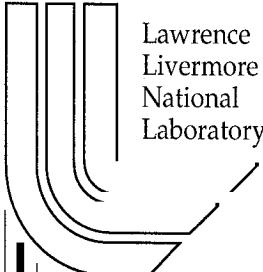


# NIF Spot Summary

*P. E. Young*

**April 13, 2000**

*U.S. Department of Energy*



## **DISCLAIMER**

This document was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor the University of California nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or the University of California, and shall not be used for advertising or product endorsement purposes.

Work performed under the auspices of the U. S. Department of Energy by the University of California Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

This report has been reproduced  
directly from the best available copy.

Available to DOE and DOE contractors from the  
Office of Scientific and Technical Information  
P.O. Box 62, Oak Ridge, TN 37831  
Prices available from (423) 576-8401  
<http://apollo.osti.gov/bridge/>

Available to the public from the  
National Technical Information Service  
U.S. Department of Commerce  
5285 Port Royal Rd.,  
Springfield, VA 22161  
<http://www.ntis.gov/>

OR

Lawrence Livermore National Laboratory  
Technical Information Department's Digital Library  
<http://www.llnl.gov/tid/Library.html>

**NIF Mission Support Memo**

Mail Station L-473

Ext: 2-5478

April 13, 2000

NIF\_0046162

To: NIF Mission Support Staff

From: Peter Young

Subject: **NIF spot summary**

We are compiling a list of anticipated target spot sizes that are specified by the NIF users groups. This data will be used to anticipate demands for phase plates. The spot size also has an impact on the laser operation. Presently the phase plates are designed to sit in the  $1\omega$  section of the FOA (before the conversion crystals). Intensity modulations produced by the phase plates are nonlinearly proportional to the laser spot size. For spot sizes above 3 mm diameter, the intensity modulations are large enough that the damage threshold for the remainder of the FOA is exceeded. For experiments requiring spot diameters larger than 3 mm, it is suggested that the phase plates sit in the  $3\omega$  section of the FOA. For planning purposes, the cost of the  $3\omega$  phase plates is presently projected to be more than that of a  $1\omega$  phase plate due to the use of inclusion-free fused silica as the substrate material.

Below is a summary of a meeting that we had on February 16, 2000 in order to catalogue the possible range of requested NIF spot sizes. Copies of the viewgraphs which were presented will be attached to this.

**Ignition hohlraums (Pollaine/Suter)**

Hohlraum optimization strategies put an upper bound on the spot sizes of 1 – 2 mm high x 2 mm wide

Scale 1 point design:

<u>Angle</u>	<u><math>\epsilon</math></u>	Size, mm
23.5°	1.12	0.67 x 0.75
30.0°	1.21	0.64 x 0.78
44.5°	1.59	0.56 x 0.89
50.0°	1.88	0.52 x 0.97

Scale 1 with large spot to reduce intensity for LPI:

<u>Angle</u>	<u><math>\epsilon</math></u>	Size, mm
23.5°	1.12	1.34 x 1.50

30.0°	1.21	1.28 x 1.56
44.5°	1.59	0.79 x 1.26
50.0°	1.88	0.74 x 1.37

High Yield spot sizes could use spots ~2 mm

23.5	2.0 x 2.2
50.0	1.4 x 2.2

### **Planar hydrodynamics experiments (J. Edwards)**

Spot diameters up to 6 mm are envisioned. Illumination uniformity is an issue but needs to be quantified.

Spot diameter (mm)	Pulse length (ns)
5.5	80
4.2	38
3.6	25
2.9	14

### **NWET experiments (Suter)**

Maximum spot diameter = 2 mm,  $I_{inner} = 5.3 \times 10^{13} \text{ W/cm}^2$ ,  $I_{outer} = 8.3 \times 10^{13} \text{ W/cm}^2$   
Pulse length ≈ 6 ns

### **SSMP (from Josh's FOA chart)**

250 – 150 μm diameter, 500 – 300 TW

### **HEDS (John Edwards)**

A few times the nominal NIF spot size, which makes it ~1.5 to 2mm. This needs to be specified more precisely.

### **Direct Drive (Richard Town, LLE)**

~ 3 mm diameter

---

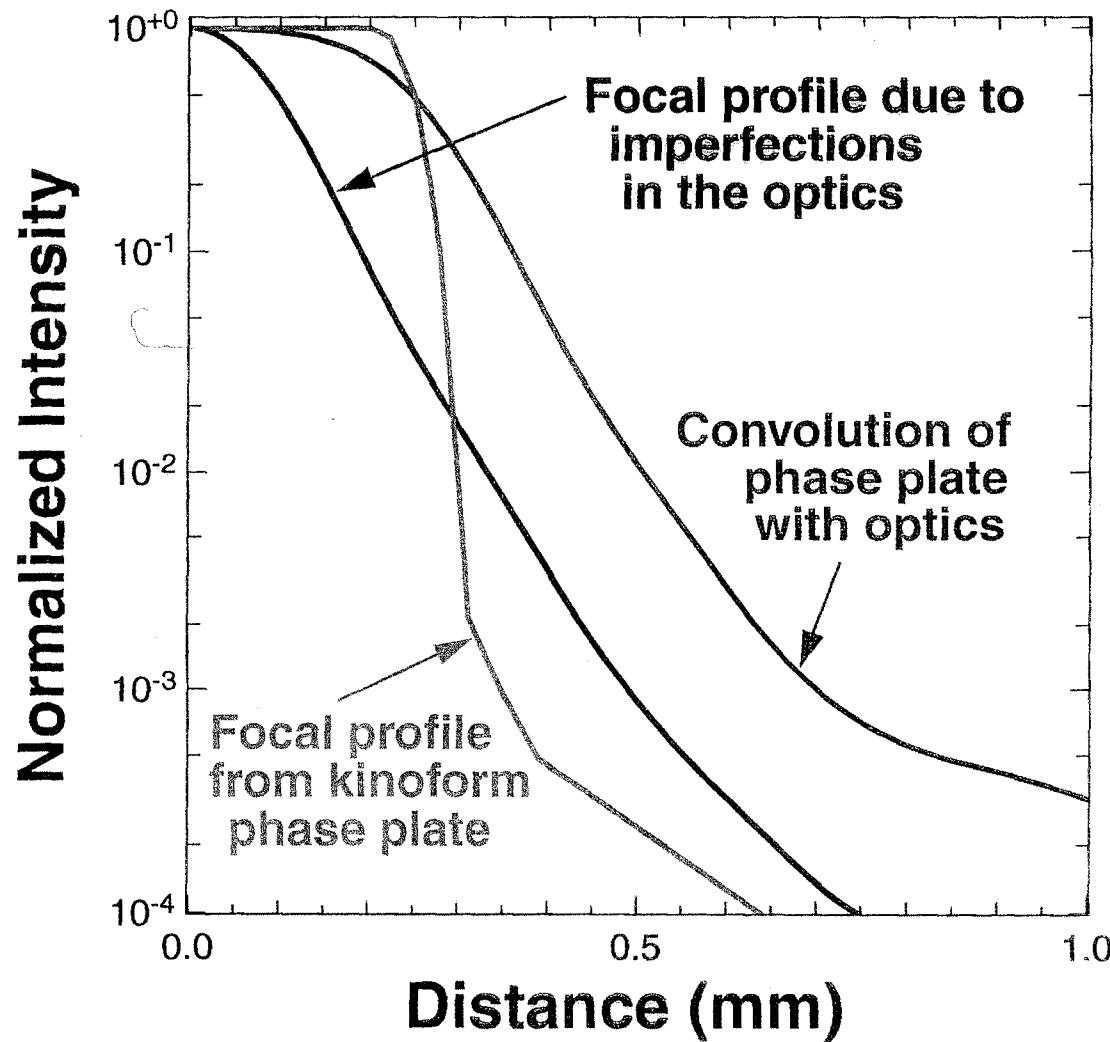
**NIF**

*The National Ignition Facility*

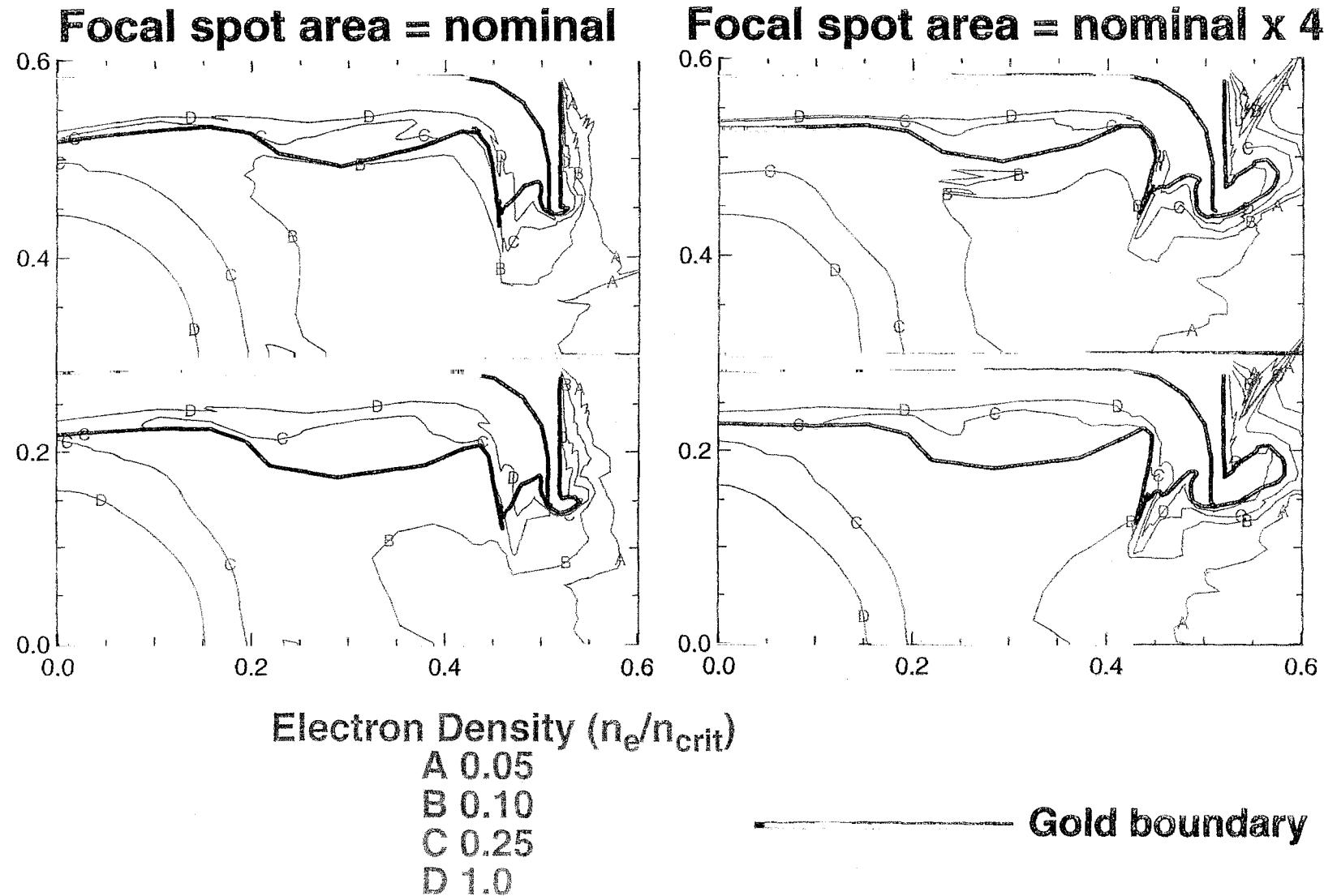
# **Ignition hohlraums**

## **Steve Pollaine**

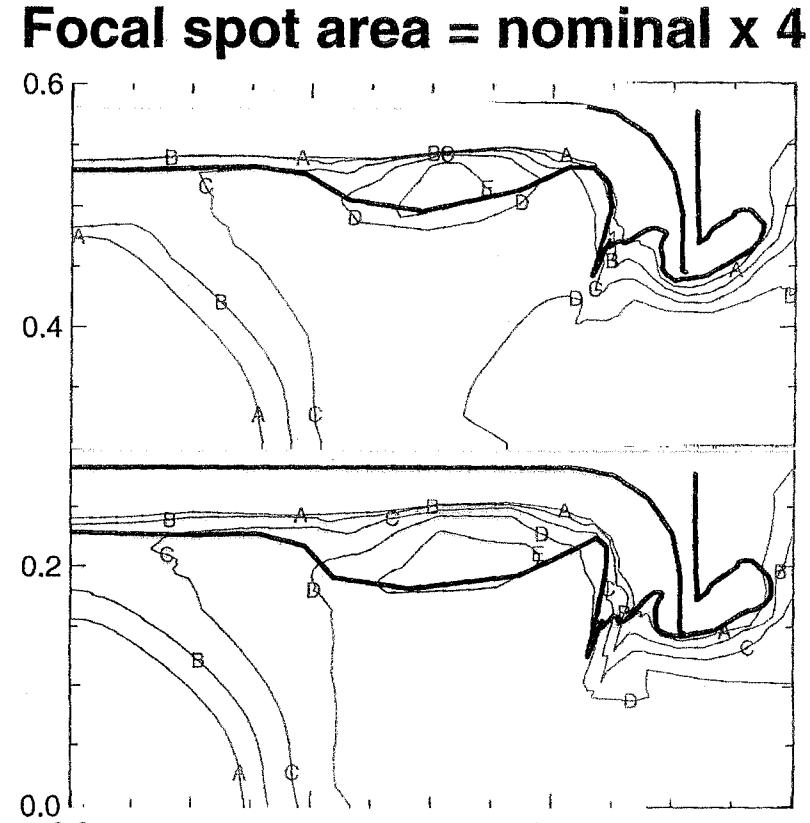
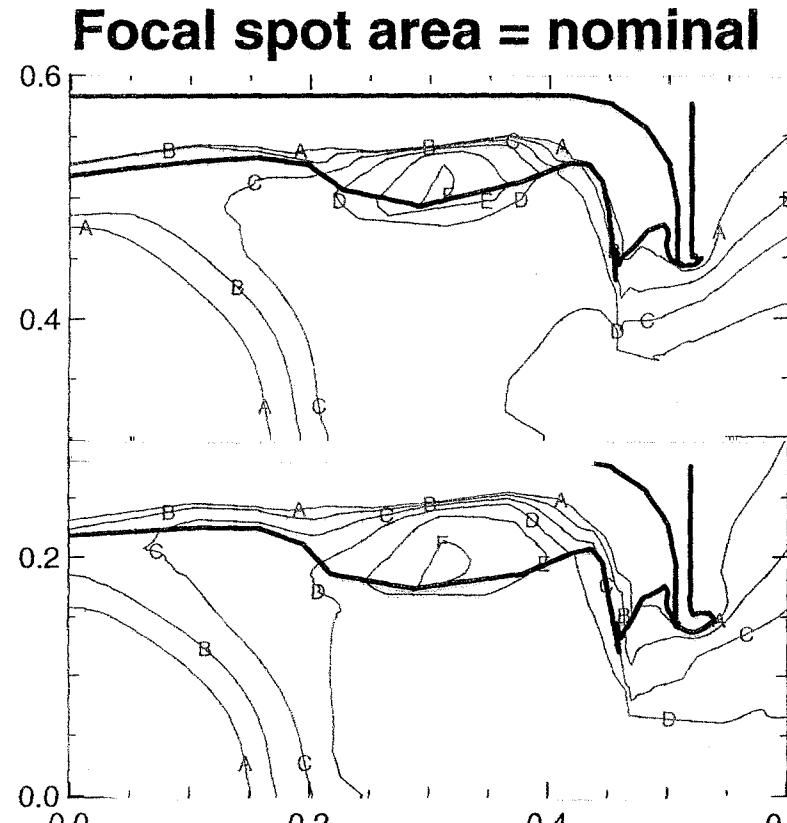
The focal plane intensity profile used in our simulations is the convolution of the kinoform phase plate profile with the profile due to optics imperfections



# At peak power, most of the hohlraum interior is at one tenth critical density



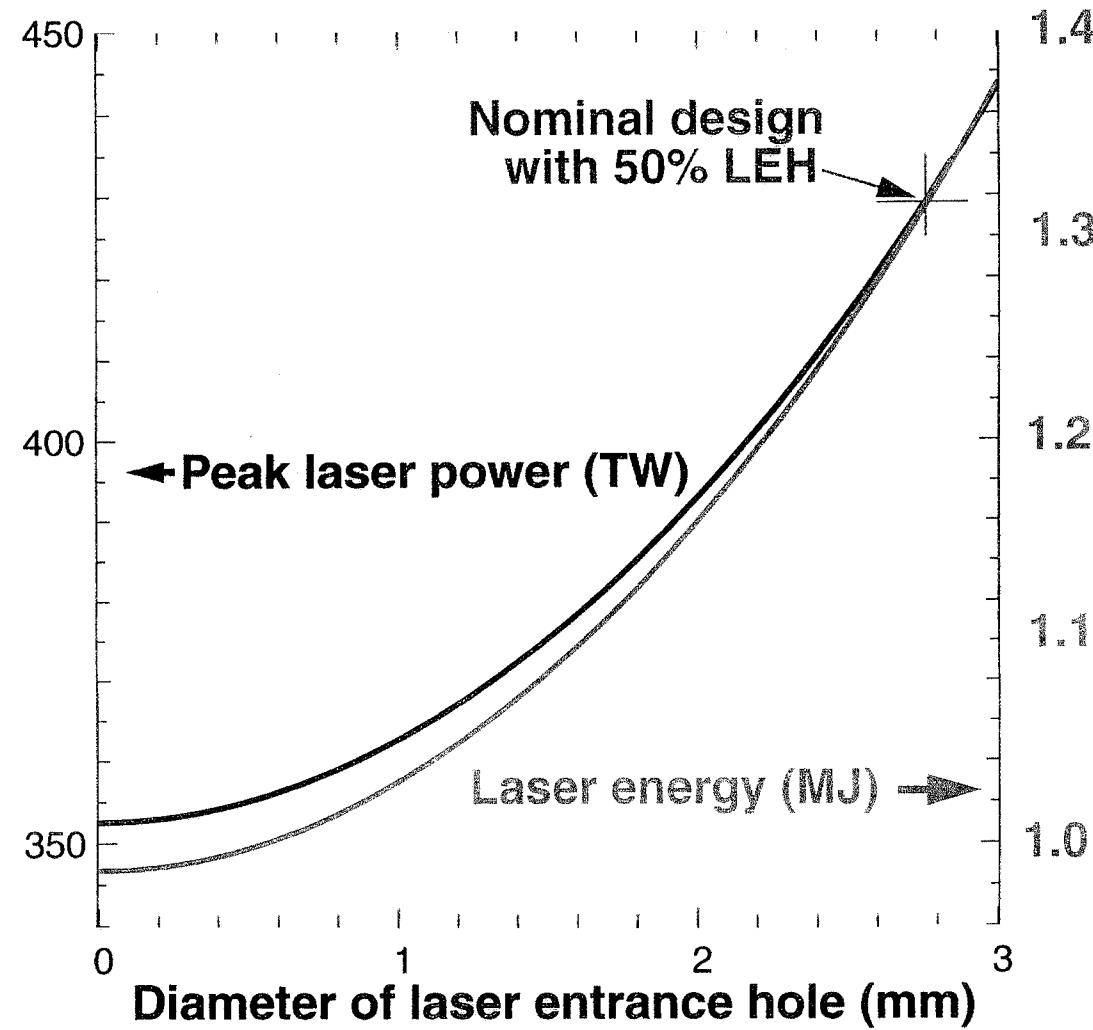
# At peak power, most of the hohlraum interior is at 4 KeV



A 1  
B 2  
C 3  
D 4  
E 5  
F 6

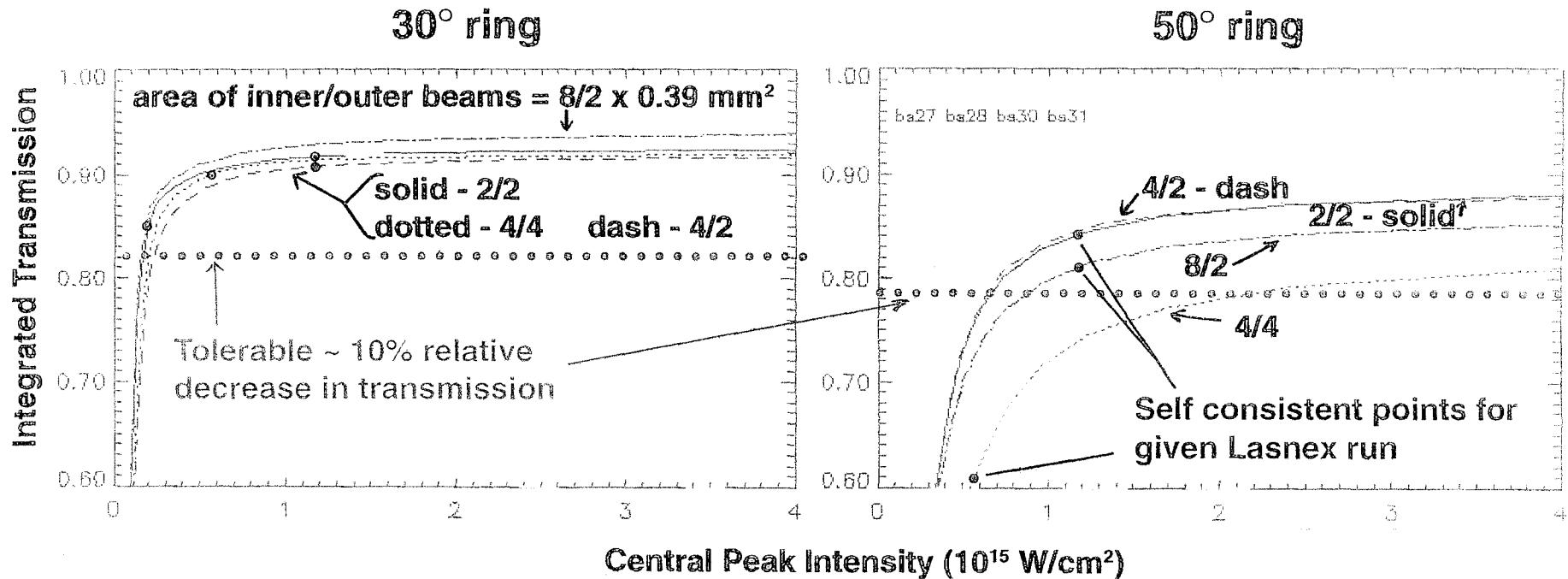
— Gold boundary

# Decreasing the size of the laser entrance hole reduces the need for laser energy and power



**Calculations indicate that considerable margin exists in both inner and outer cones to decrease the central intensity – without significant increase in plasma absorption**

Calculated integrated inverse bremsstrahlung transmission of entire focal beam as a function of beam size (plotted as a function of central peak intensity). Each transmission curve is based on the plasma calculated from a Lasnex run in which the assumed beam size is constant as labeled.



Curves are labeled with the assumed focal beam areas of the inner/outer rings in a given Lasnex calculation as a multiple of the NIF baseline area of  $\pi \cdot (0.5 \text{ mm}) \cdot (0.25 \text{ mm}) = 0.39 \text{ mm}^2$

In our LASNEX simulations, we minimized absorption  
by optimizing the eccentricity of each beam cone



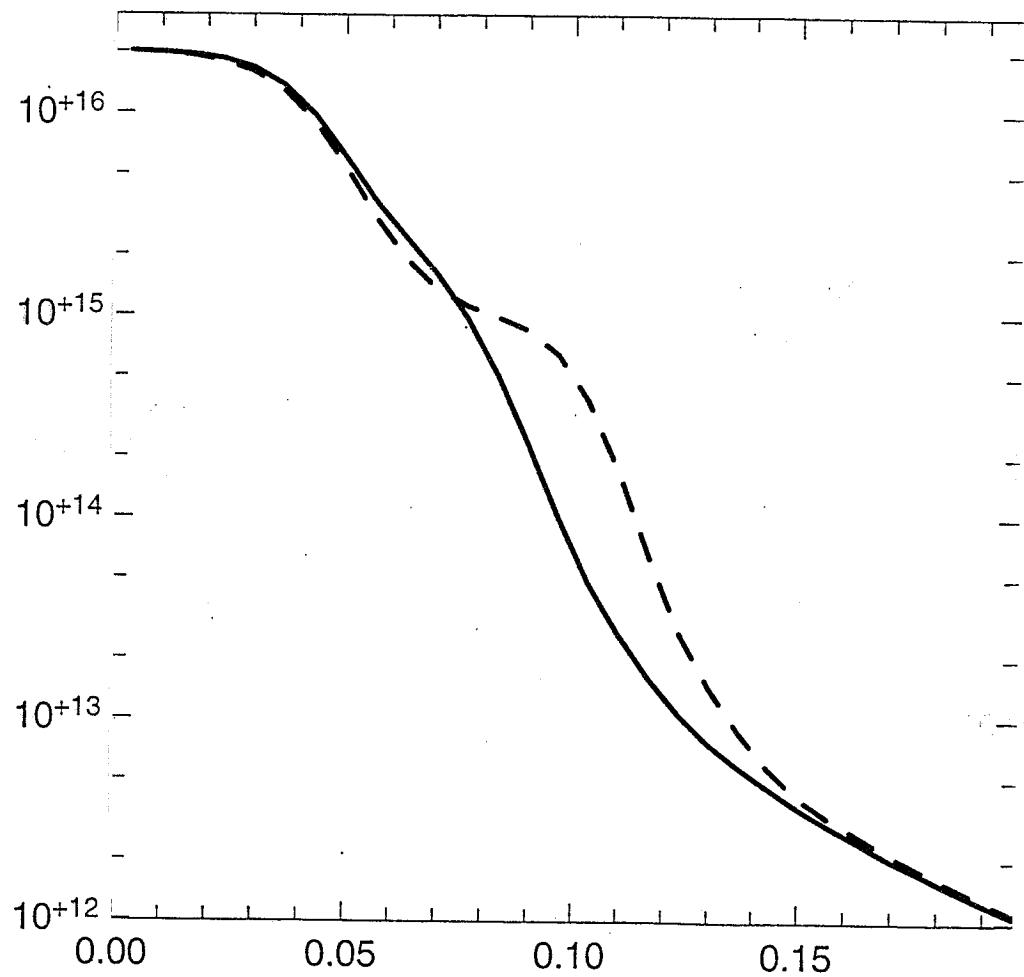
PT hohlraum requires 430 TW  
This is  $430/48 = 9.0$  TW per quad

For the nominal focal spot size of 0.5 mm x 1.0 mm,  
the area is  $0.39 \text{ mm}^2$  and the intensity per quad is  
 $2.3 \times 10^{15} \text{ W/cm}^2$

Beam cone angle	Eccentricity*	Dimensions (mm) with same area of $0.39 \text{ mm}^2$
$23.5^\circ$	1.12	$0.67 \times 0.75$
$30.0^\circ$	1.21	$0.64 \times 0.78$
$44.5^\circ$	1.59	$0.56 \times 0.89$
$50.0^\circ$	1.88	$0.52 \times 0.97$

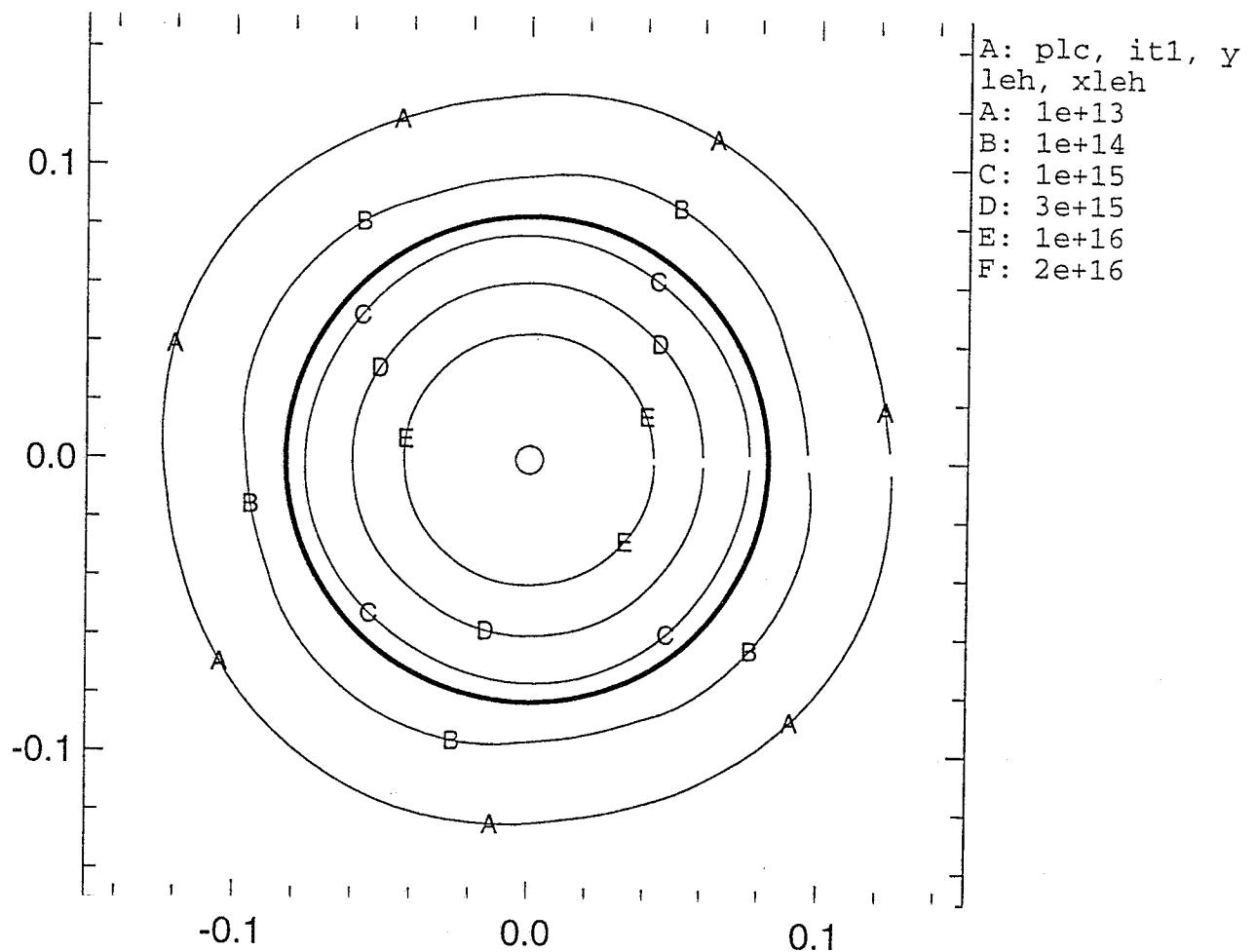
\* As we vary the size of each ellipse, we keep the eccentricity of each focal spot constant

Total intensity vs radius, move 11.25 (dash)

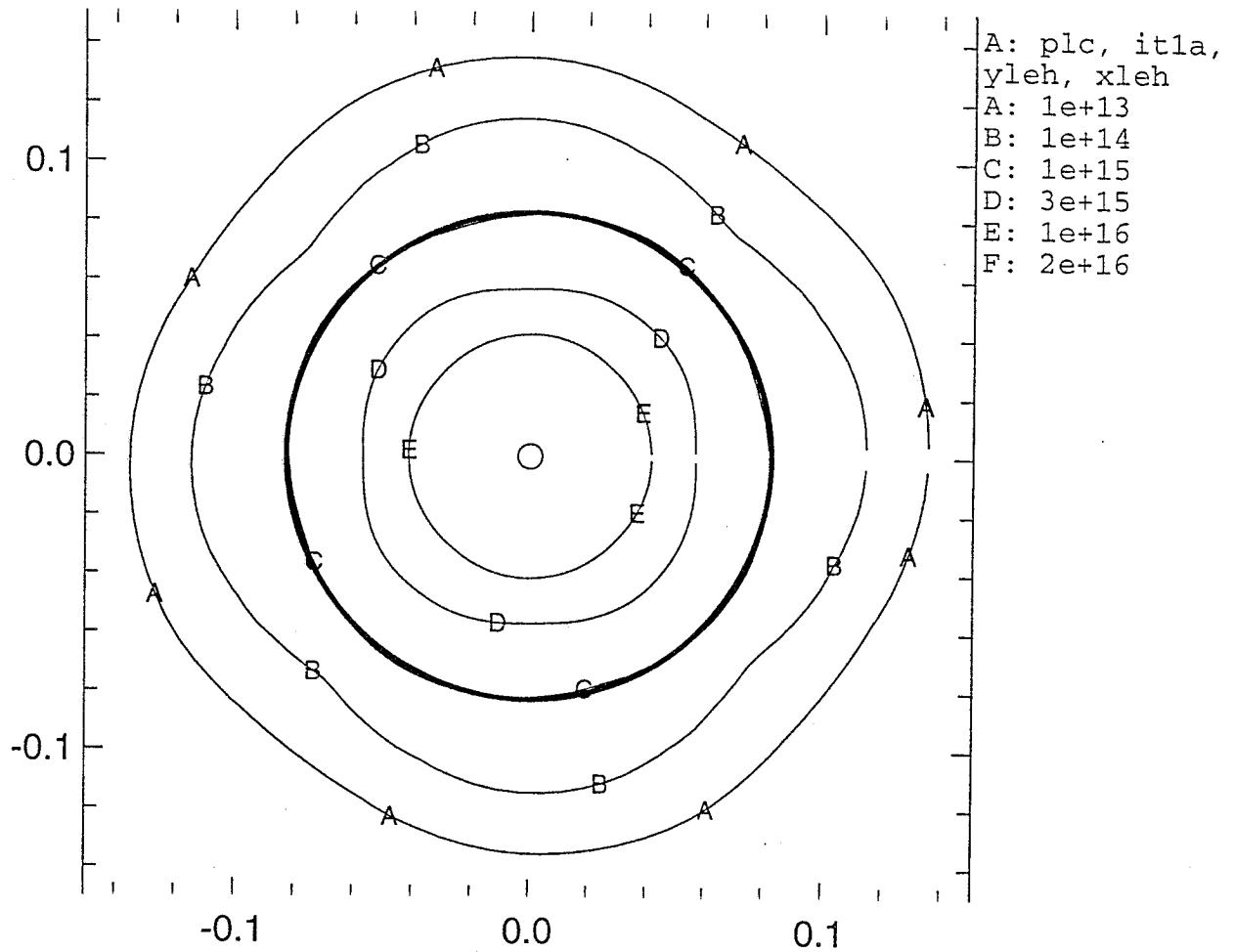


A: plg, it1(,72), yleh(,72)  
B: plg, it1(,24), yleh(,24)  
C: plg, it1a(,72), yleh(,72)  
D: plg, it1a(,24), yleh(,24)

Total intensity for 0.6 scale

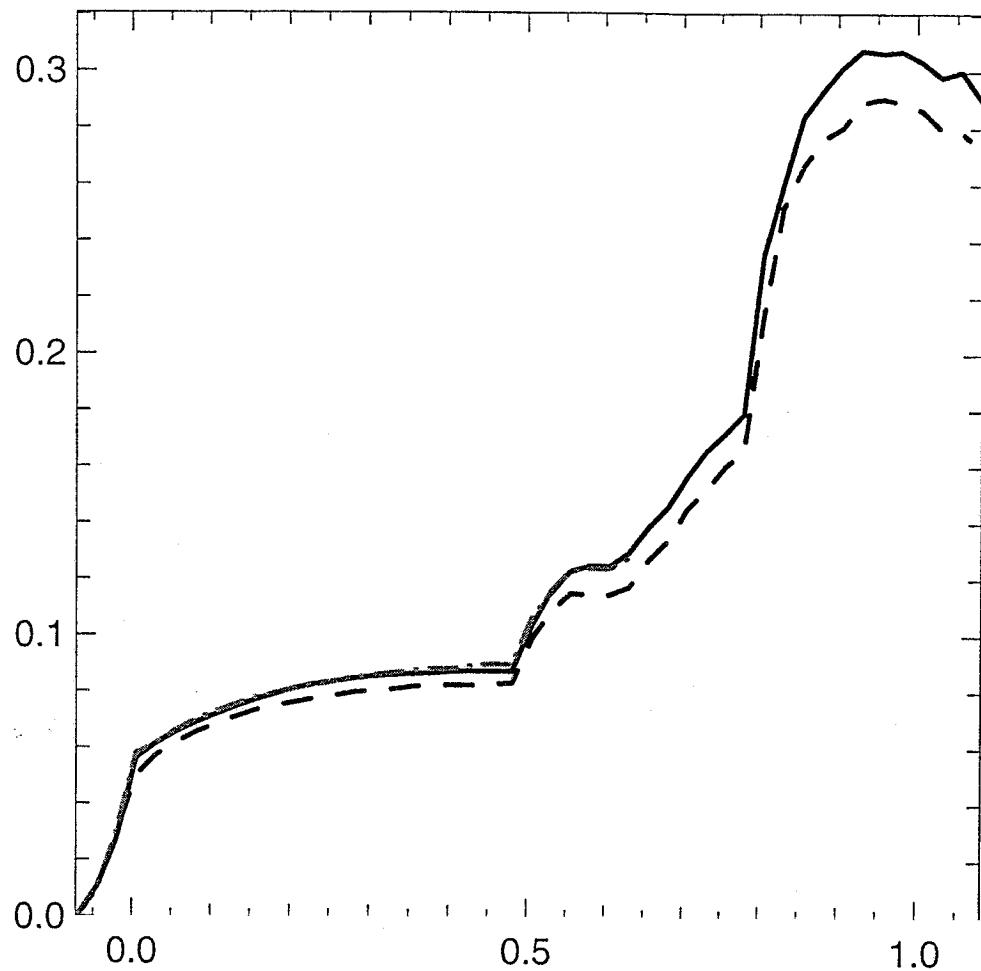


Total intensity for 0.6 scale, move 30 beam 11.25 deg



A: plc, it1a, yleh, xleh  
circle

Tr hf10(solid), 10a-11.25(dash), 10b-11.25+small(dot-dash)

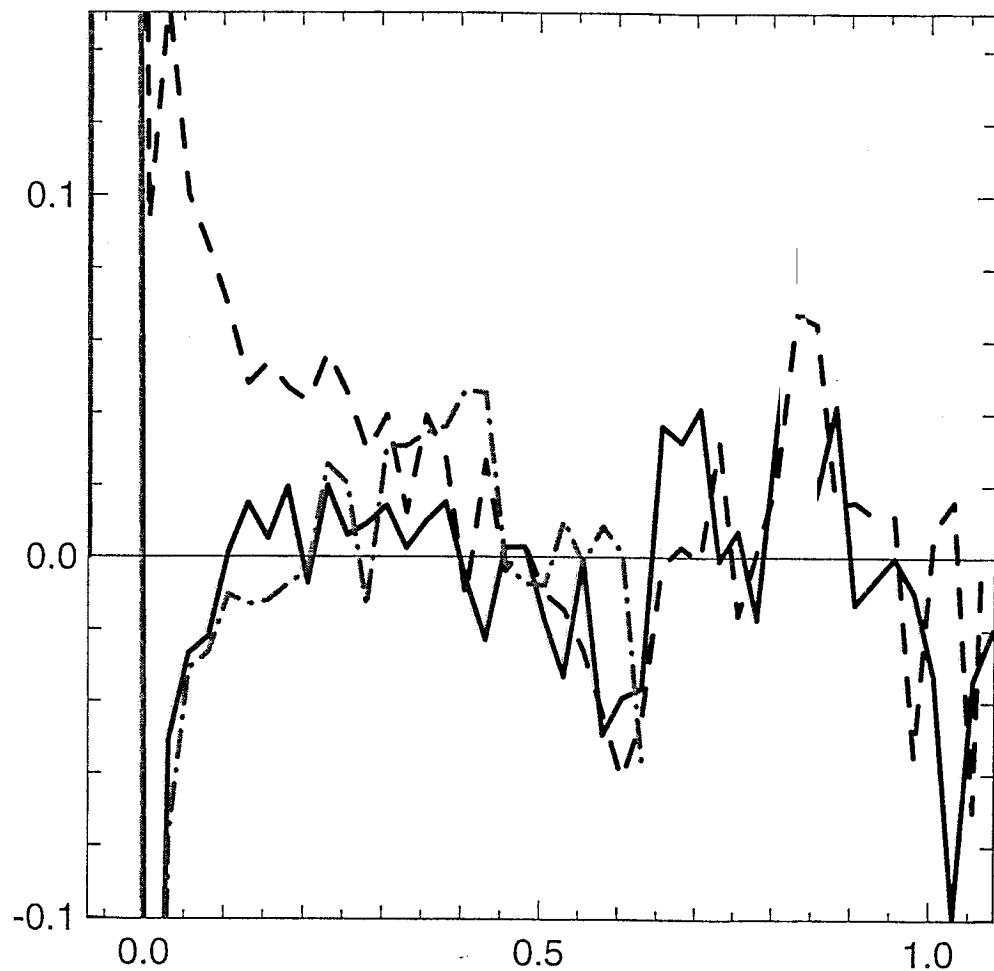


A: plg, f.p0^.25, f.times

B: plg, a.p0^.25, a.times

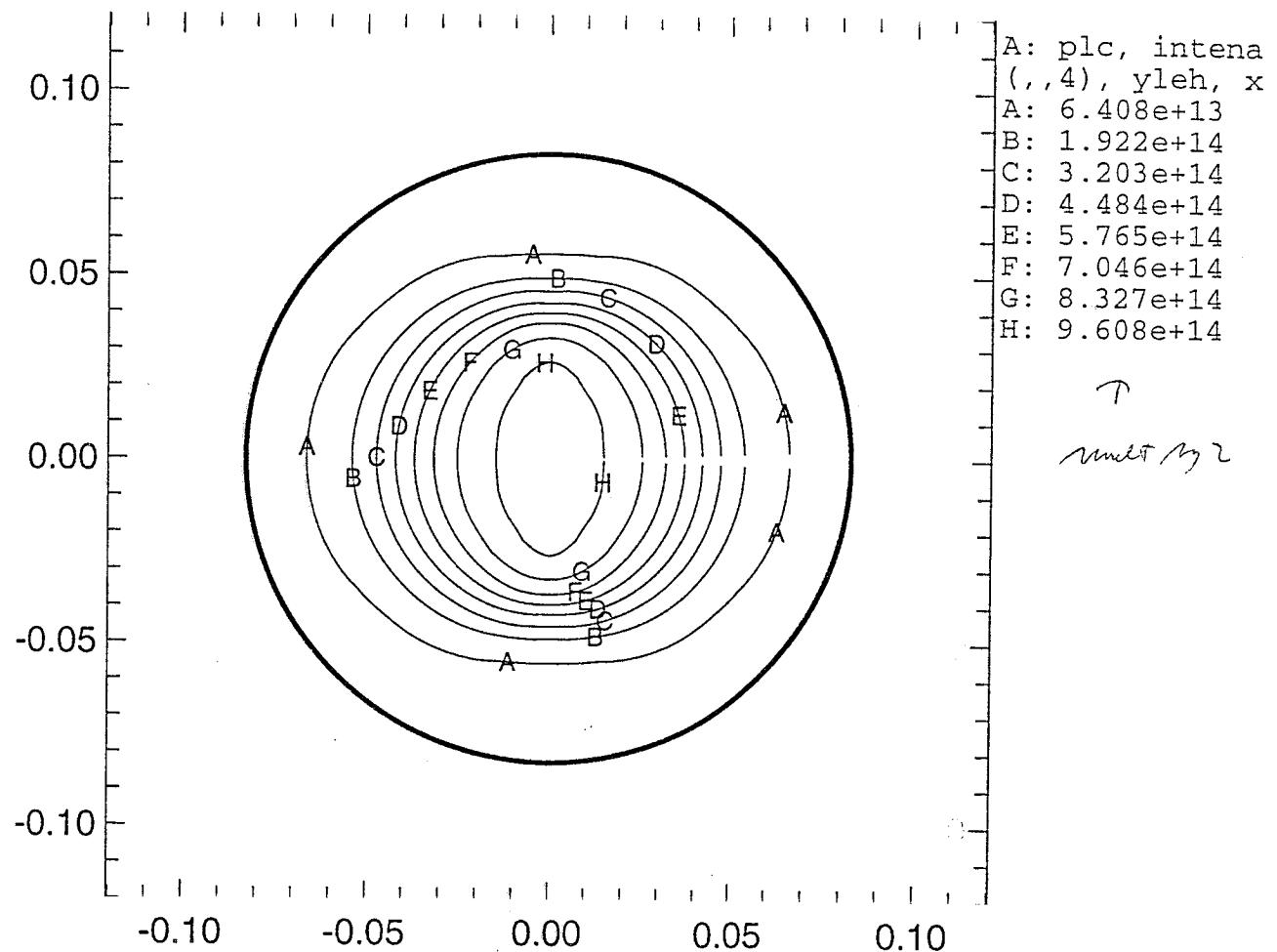
C: plg, b.p0^.25, b.times

P2/P0, hf10(solid), 10a-11.25(dash), 10b-11.25+small(dot-dash)

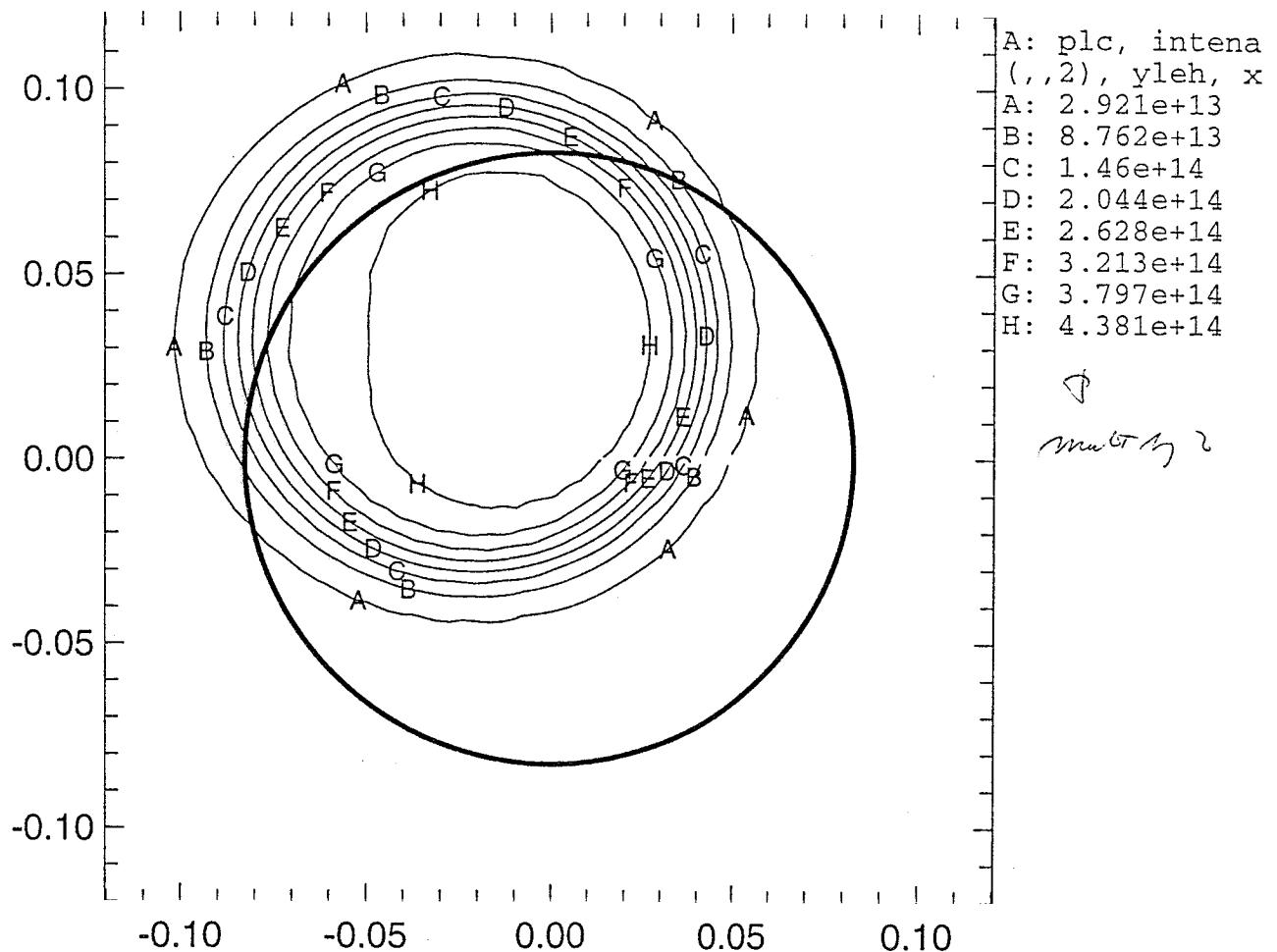


A: plg, f.p2p0, f.times  
B: plg, a.p2p0, a.times  
C: plg, b.p2p0, b.times  
0

0.6 scale 50 deg. beam in LEH

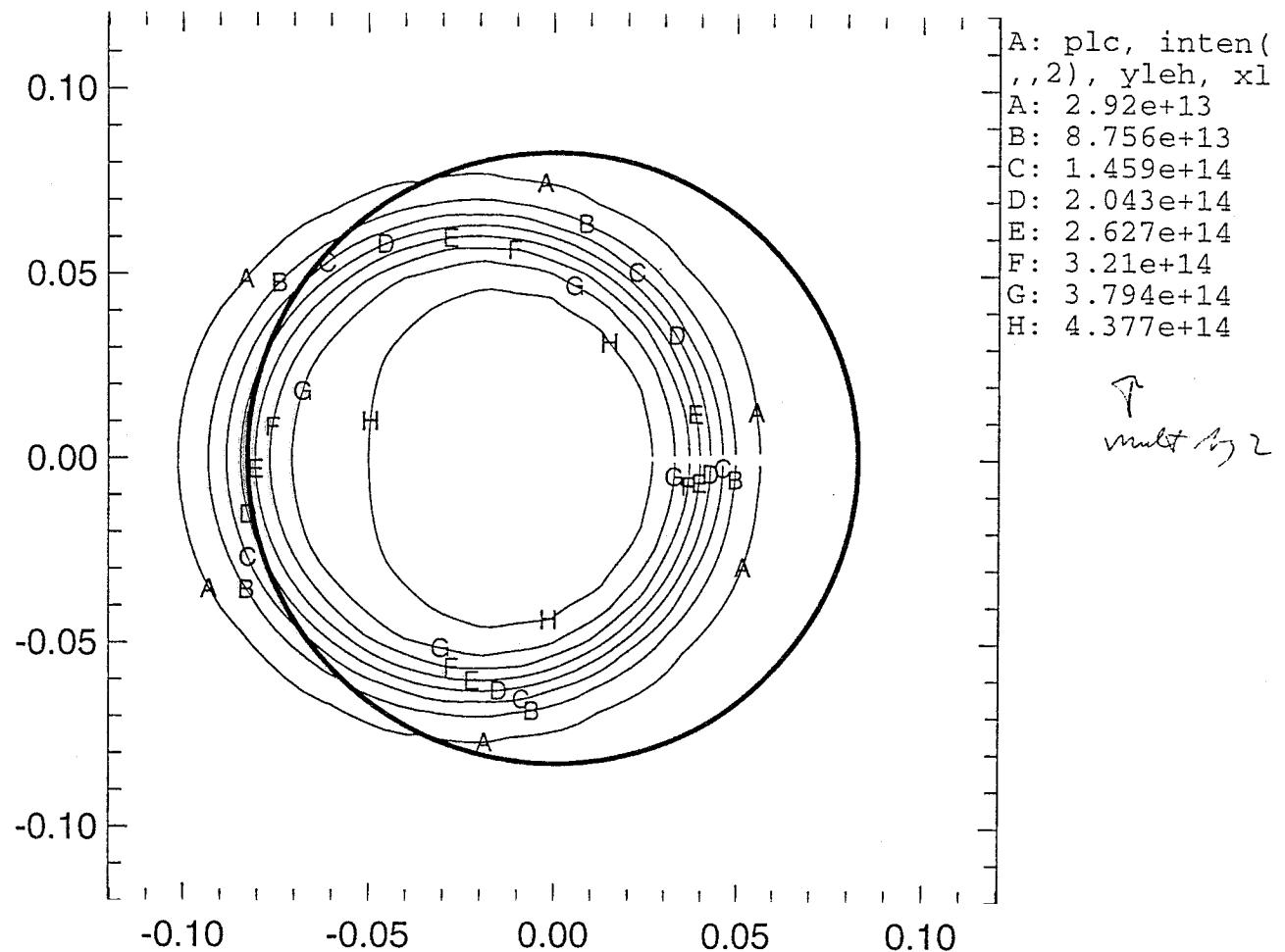


0.6 scale 30 deg. beam in LEH, moved 11.25 deg

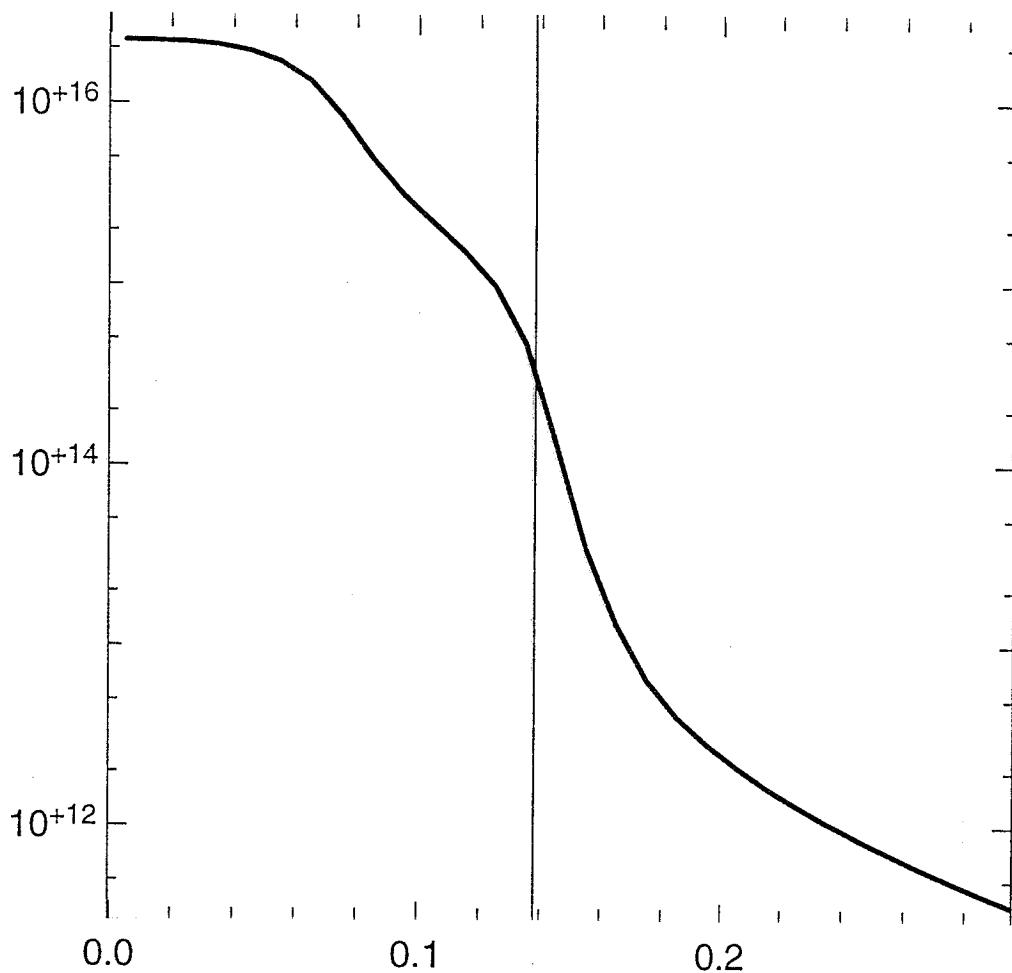


A: plc, intena(,,2), yleh, xleh  
circle

### 0.6 scale 30 deg. beam in LEH

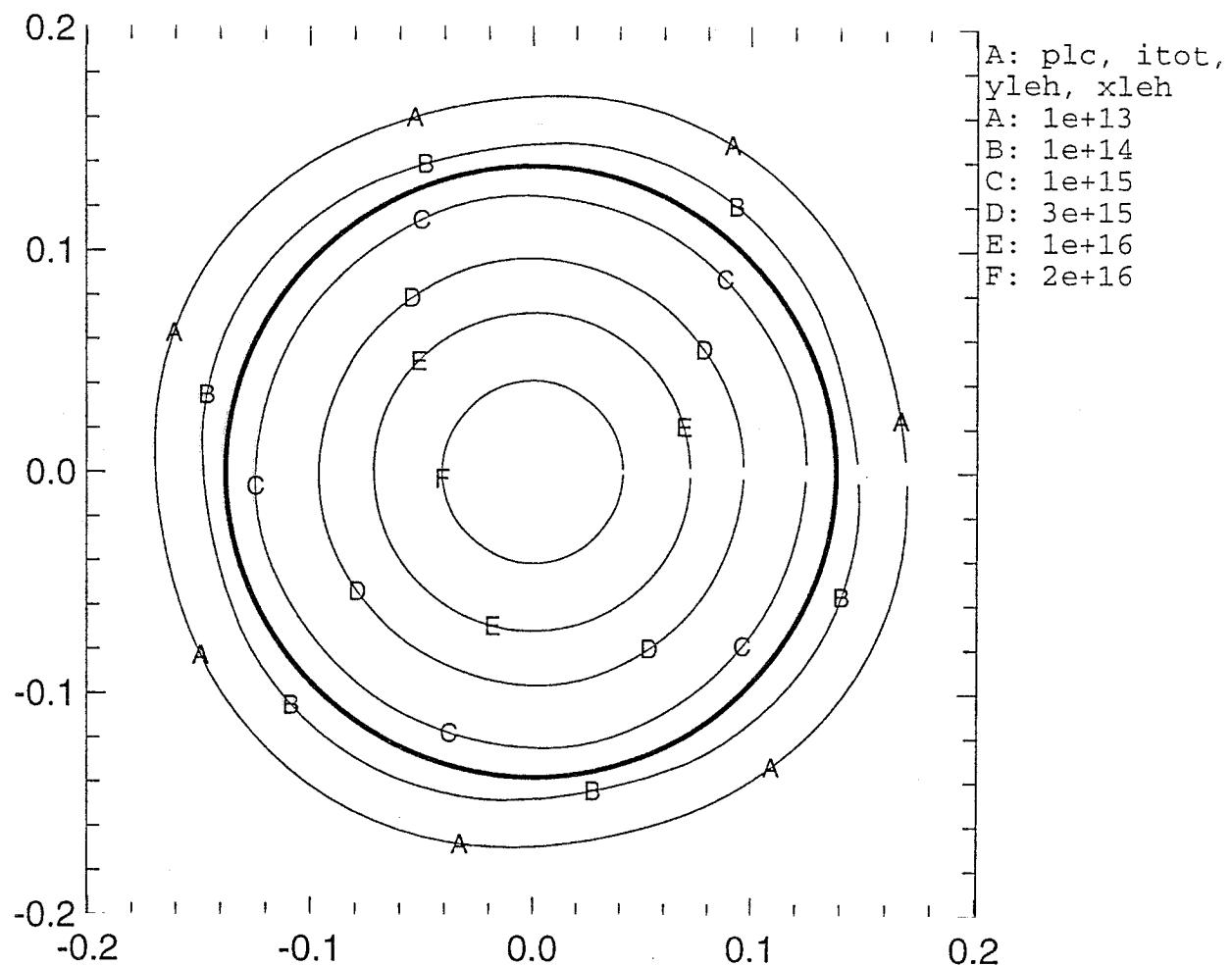


Total intensity vs radius, full NIF



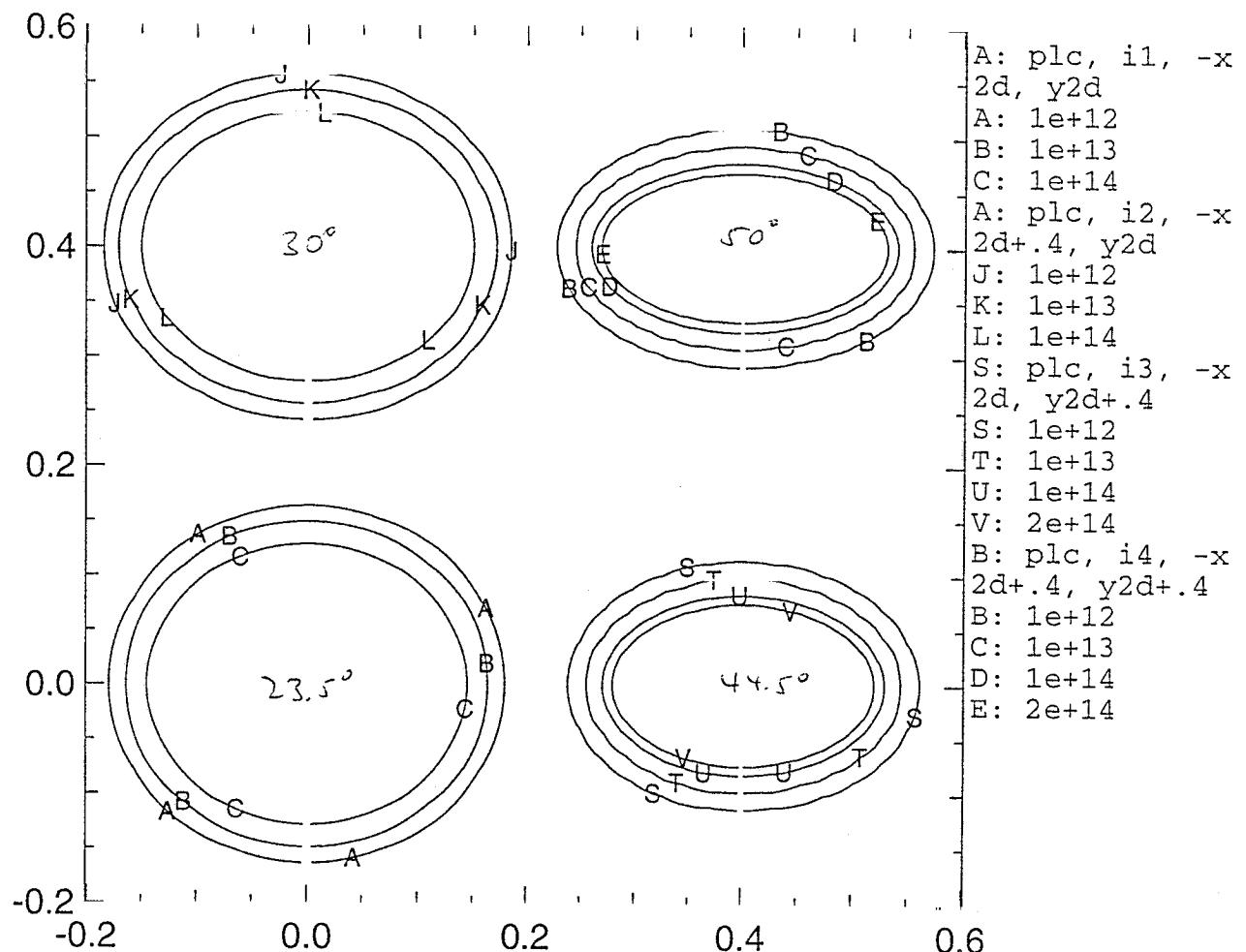
A: plg, itot(,24), yleh(,24)  
0.138

### Total intensity vs radius for scale 1 NIF



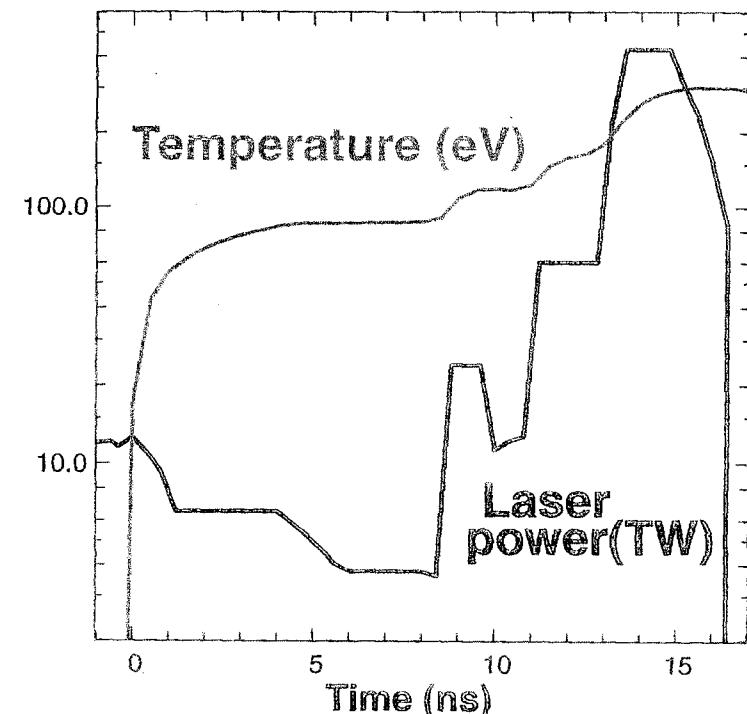
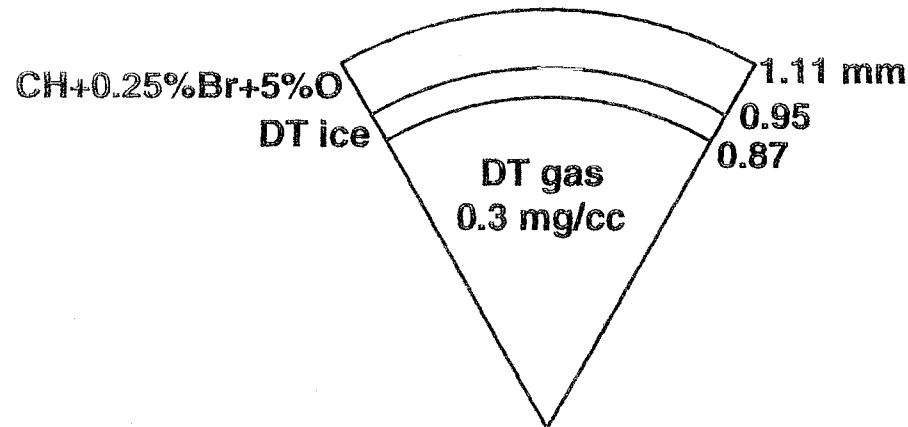
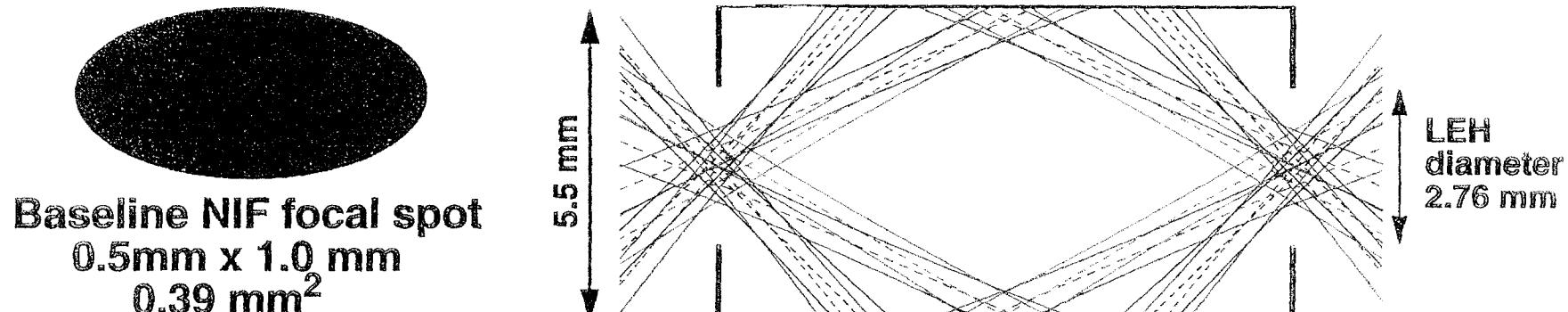
A: plc, itot, yleh, xleh  
circle

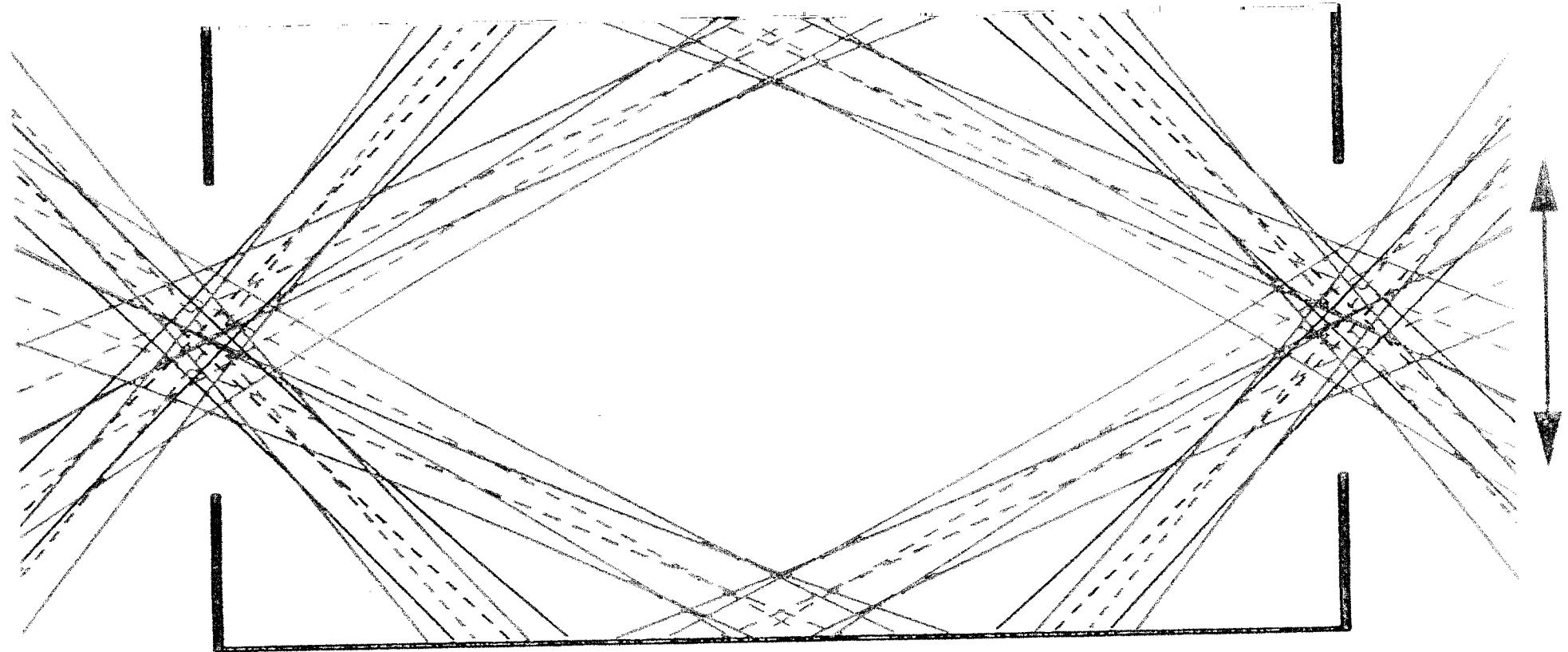
## Standard NIF beams



A: plc, i1, -x2d, y2d  
 A: plc, i2, -x2d+.4, y2d  
 S: plc, i3, -x2d, y2d+.4  
 B: plc, i4, -x2d+.4, y2d+.4

We used the standard PT hohlraum to investigate the effect of different NIF focal spot sizes

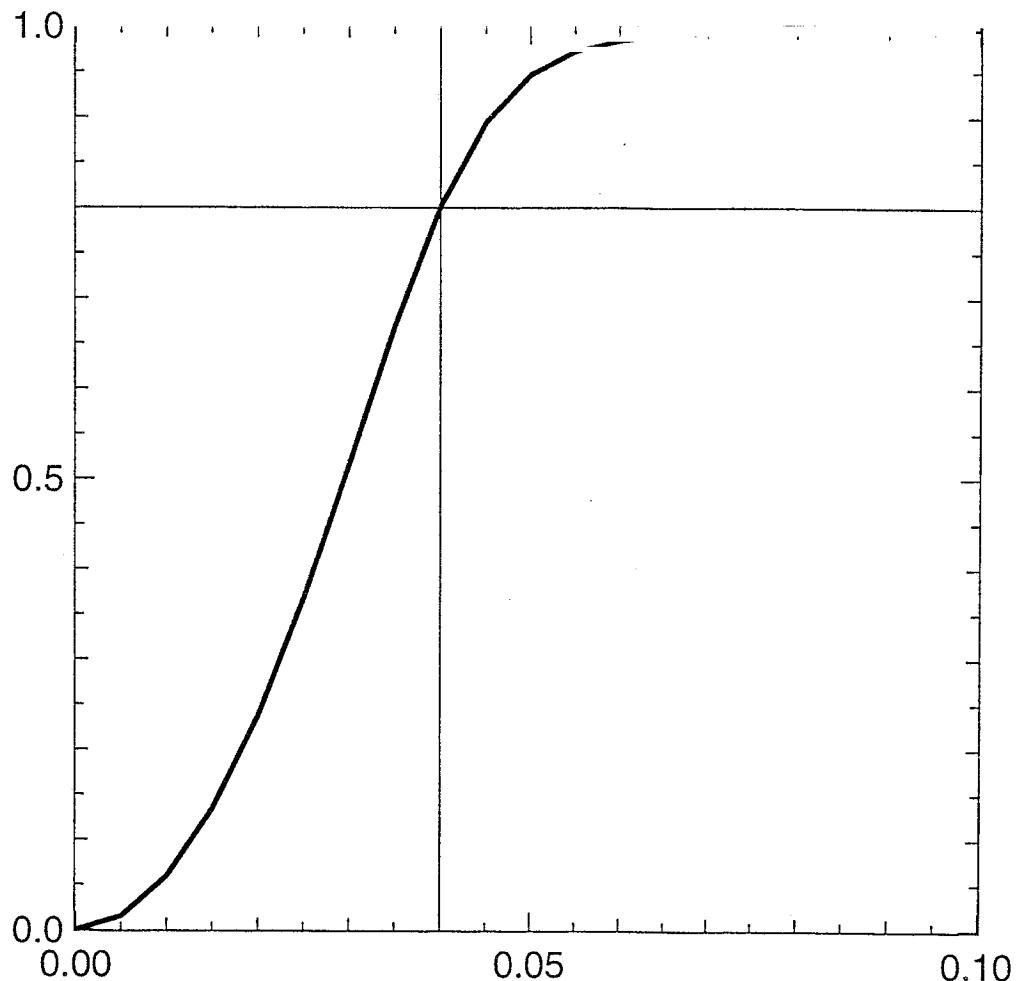




10 mm

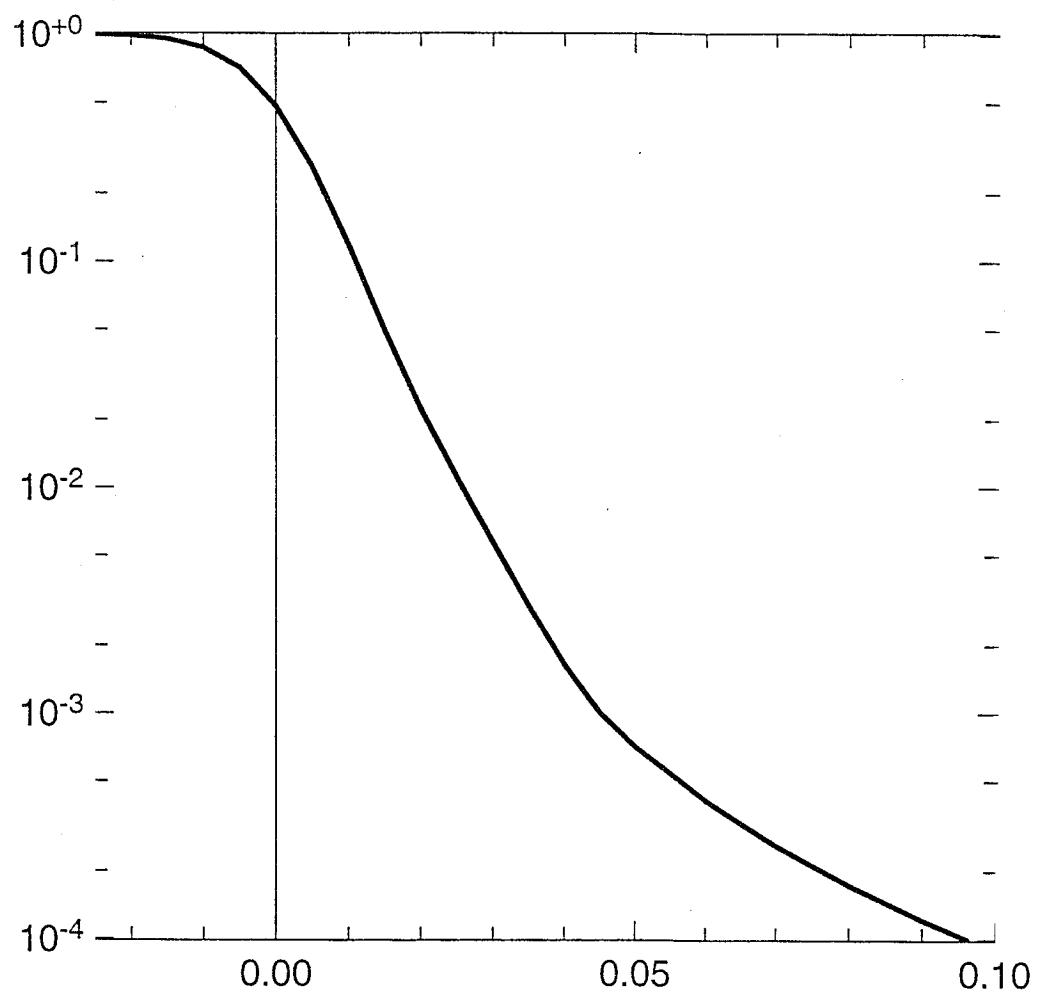


Energy inside radius vs radius



A: plg, e, d9  
0.04  
0.8

Intensity vs Radius



A: plg, inten8, d8  
0

---

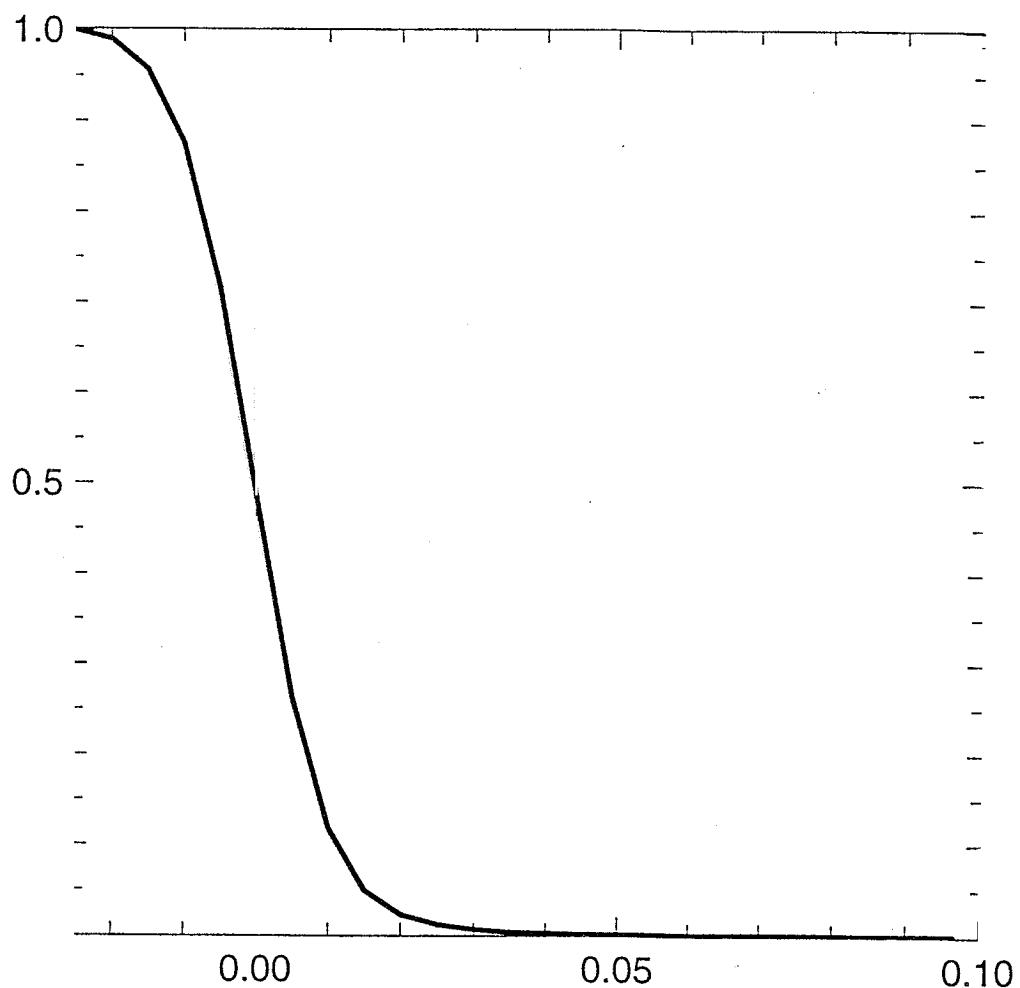
**NIF**

*The National Ignition Facility*

# **Ignition hohlraums and NWET**

## **Larry Suter**

Intensity vs Radius

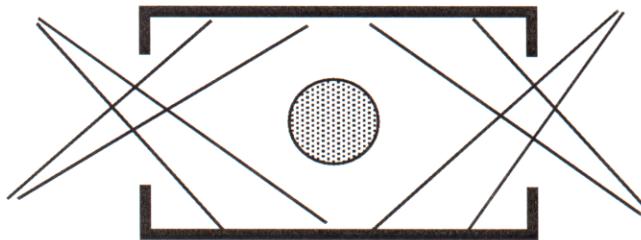


A: plg, inten8, d8  
0

# High yield designs typically allow a bigger spot



Scale 1.0 NIF  
(= scale 3.45 Nova)



Point Design

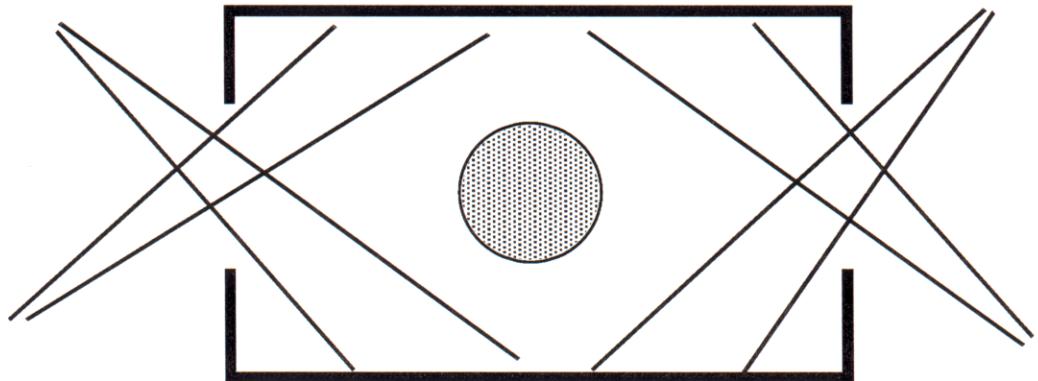
Tr=~300eV

Ecap=150kJ

Elaser~450TWx3ns=1.35MJ

Y ~ 15MJ

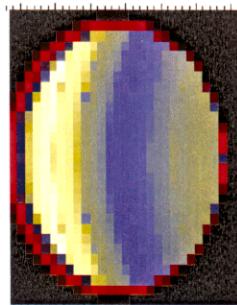
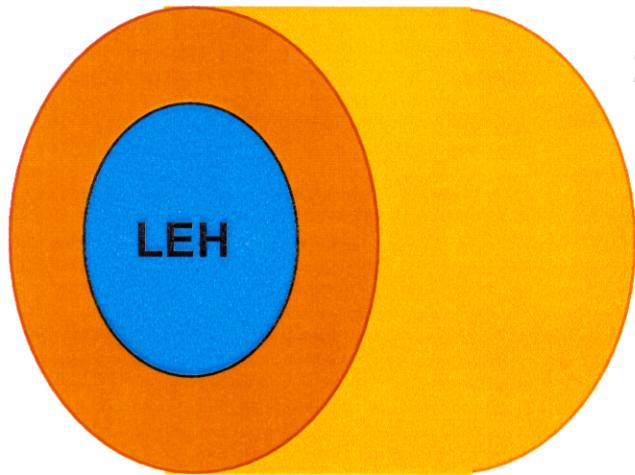
Scale 1.61 NIF  
(5.55 Nova)



A 600kJ design  
Tr=~270eV  
Ecap=600kJ  
Elaser~ 300TWx8ns=2.4MJ  
Y ~ 120MJ

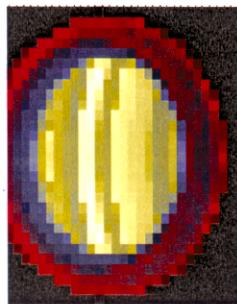
Even though such targets have a reduced fractional LEH area,  
the absolute LEH size is bigger

Currently, we let the LEH dynamically close to an effective area ~60% of the original hole's area



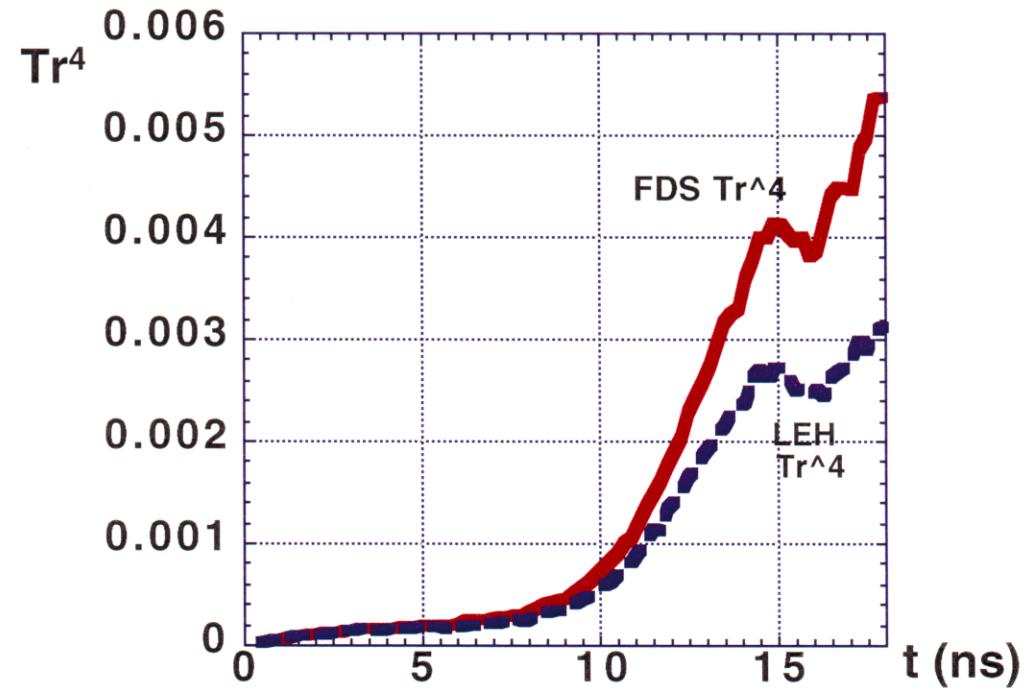
5ns

Synthetic  
images of  
the LEH  
from 37°



18ns

2D simulations show the LEH can partially close



In all our 2D simulations the effective hole area is ~60% of geometric

Diameter is ~80% of geometric

With 192 beams, high yield hohlraum size might range from ~ scale 1.25 to 1.6

NIF

The National Ignition Facility



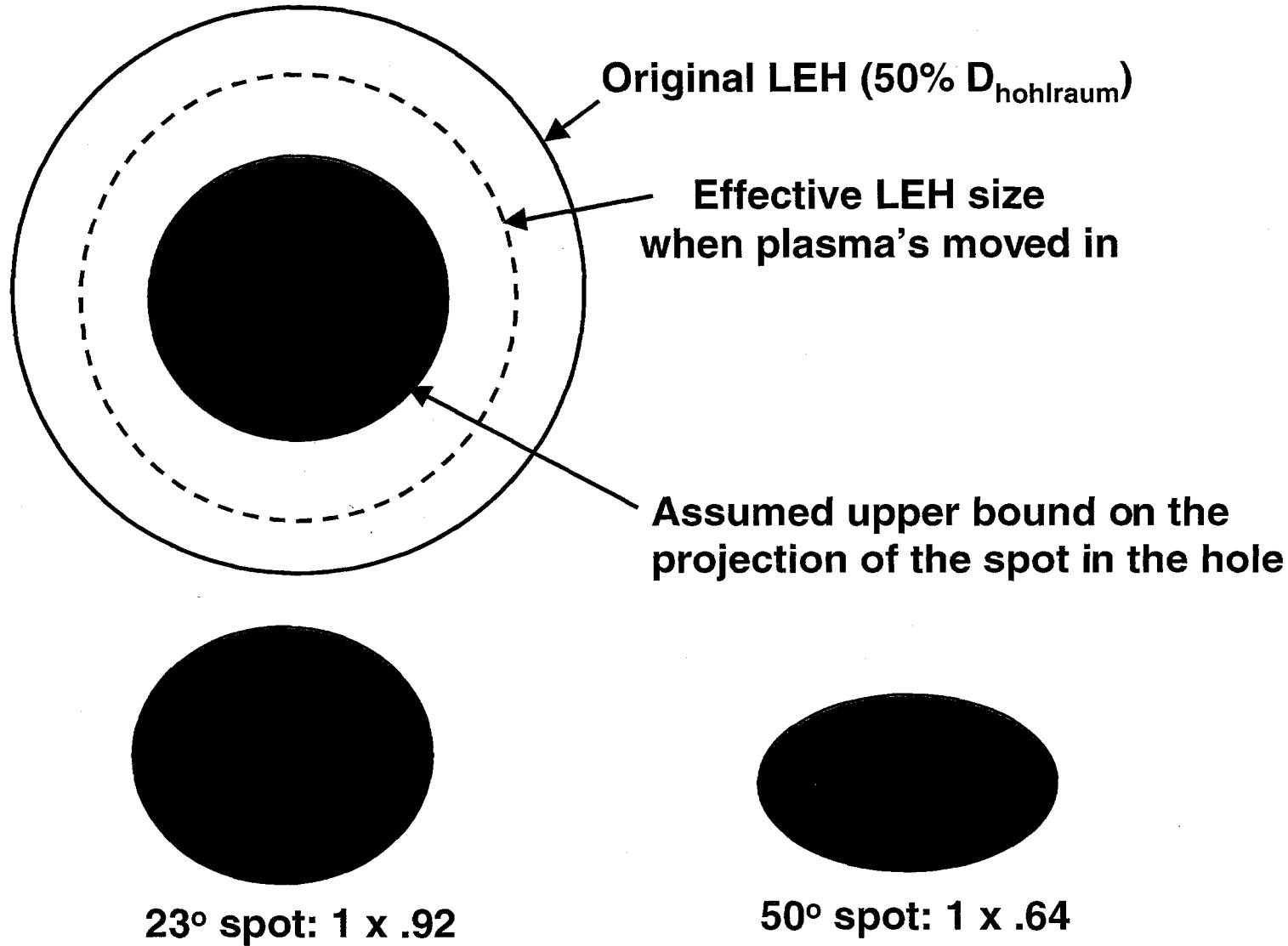
1.0 NIF = 3.45 Nova

Tr	N beams	Rcc	limit	Ecap (kJ)	hohlraum scale
300	192	3.65	damage	350	1.26
300	192	3.28	damage	450	1.23
300	192	3.65	B-int	500	1.42
300	192	3.28	B-int	650	1.39
250	192	3.65	damage	600	1.61
250	192	3.28	damage	700	1.52
250	192	3.65	1w energy	700	1.69
250	192	3.28	1w energy	850	1.62

We can estimate an upper bound on spot size by assuming maximum  $D_{\text{spot}} \sim 0.5D_{\text{geometric}}$  of the LEH

NIF

The National Ignition Facility



This assumption leads to upper bounds on spot sizes  
 ~2mm wide by 1-2mm high

**NIF**

The National Ignition Facility



Tr	Rcc	limit	Ecap (kJ)	scale	LEH diameter	Max spot width	Max 50 deg spot height
300	3.65	damage	350	1.26	0.35	0.17	0.11
300	3.28	damage	450	1.23	0.34	0.17	0.11
300	3.65	B-int	500	1.42	0.39	0.20	0.13
300	3.28	B-int	650	1.39	0.38	0.19	0.12
250	3.65	damage	600	1.61	0.44	0.22	0.14
250	3.28	damage	700	1.52	0.42	0.21	0.14
250	3.65	1w energy	700	1.69	0.47	0.23	0.15
250	3.28	1w energy	850	1.62	0.45	0.22	0.14

sizes in cm

While smaller spots could be used, the relatively low intensities of bigger spots make them worth a struggle

NIF

The National Ignition Facility



Tr	Rcc	limit	Ecap (kJ)	scale	Max Plaser (TW)	Max outer I (quad)	Max inner I (quad)
300	3.65	damage	350	1.26	540	7.4E+14	4.8E+14
300	3.28	damage	450	1.23	529	7.6E+14	4.9E+14
300	3.65	B-int	500	1.42	661	7.2E+14	4.6E+14
300	3.28	B-int	650	1.39	652	7.3E+14	4.7E+14
250	3.65	damage	600	1.61	380	3.2E+14	2.0E+14
250	3.28	damage	700	1.52	332	3.1E+14	2.0E+14
250	3.65	1w energy	700	1.69	415	3.1E+14	2.0E+14
250	3.28	1w energy	850	1.62	371	3.1E+14	2.0E+14

## Similar tables for 96 beams



Tr	Rcc	limit	Ecap (kJ)	scale	LEH diam	Max spot diam	Max 50 deg spot height
300	3.65	damage	130	0.90	0.25	0.12	0.08
300	3.28	damage	180	0.90	0.25	0.12	0.08
300	3.65	B-int	170	0.99	0.27	0.14	0.09
300	3.28	B-int	200	0.94	0.26	0.13	0.08
250	3.65	damage	220	1.15	0.32	0.16	0.10
250	3.28	damage	300	1.15	0.32	0.16	0.10
250	3.65	1w energy	350	1.34	0.37	0.19	0.12
250	3.28	1w energy	450	1.31	0.36	0.18	0.12

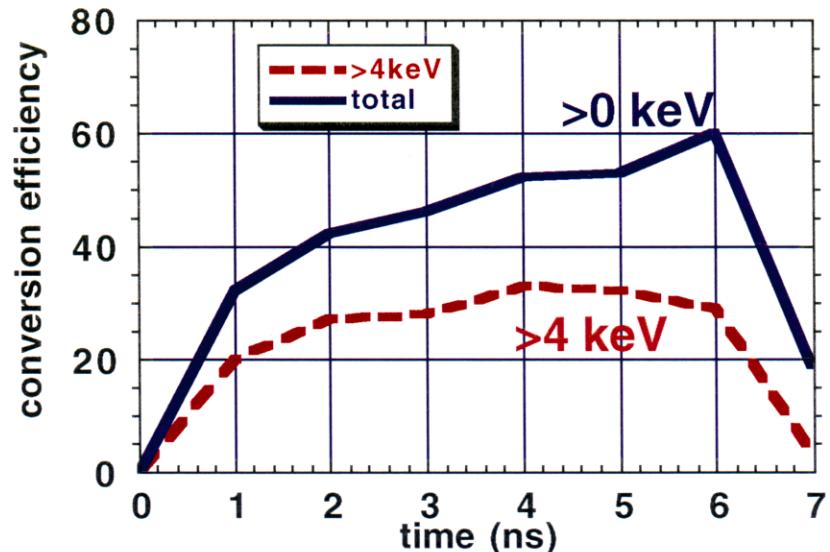
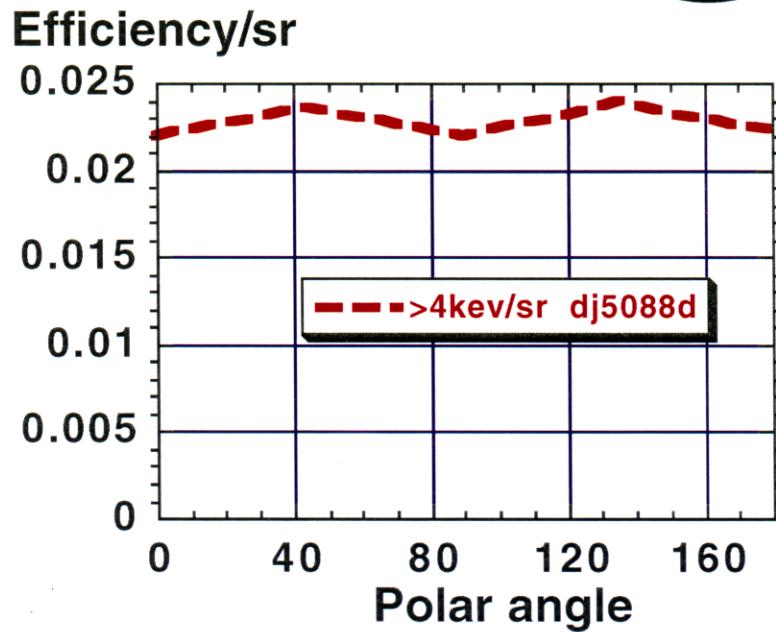
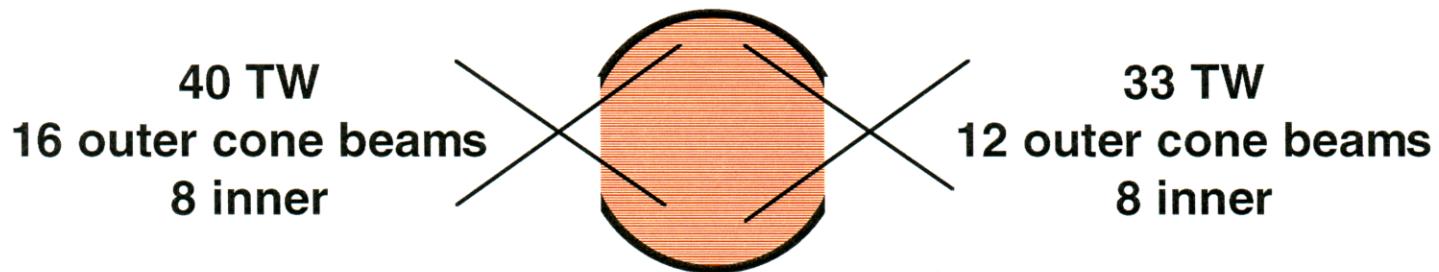
Tr	Ecap (kJ)	scale	Max Plaser	Max outer I (quad)	Max inner I (quad)
300	130	0.90	305	1.6E+15	1.0E+15
300	180	0.90	308	1.6E+15	1.0E+15
300	170	0.99	354	1.6E+15	1.0E+15
300	200	0.94	327	1.6E+15	1.0E+15
250	220	1.15	215	7.0E+14	4.5E+14
250	300	1.15	205	6.8E+14	4.3E+14
250	350	1.34	280	6.7E+14	4.3E+14
250	450	1.31	258	6.5E+14	4.2E+14

Half the beams doubles the single quad intensity

A typical NIF/NWET source might be  
a 7.2mm diameter sphere with a 4mm LEH



Be sphere filled w/ 1atm Xe  
It averages 25% >4keV production over 6ns



NWET spots which fill half the LEH  
would be ~2mm by 1.3-2mm

NIF

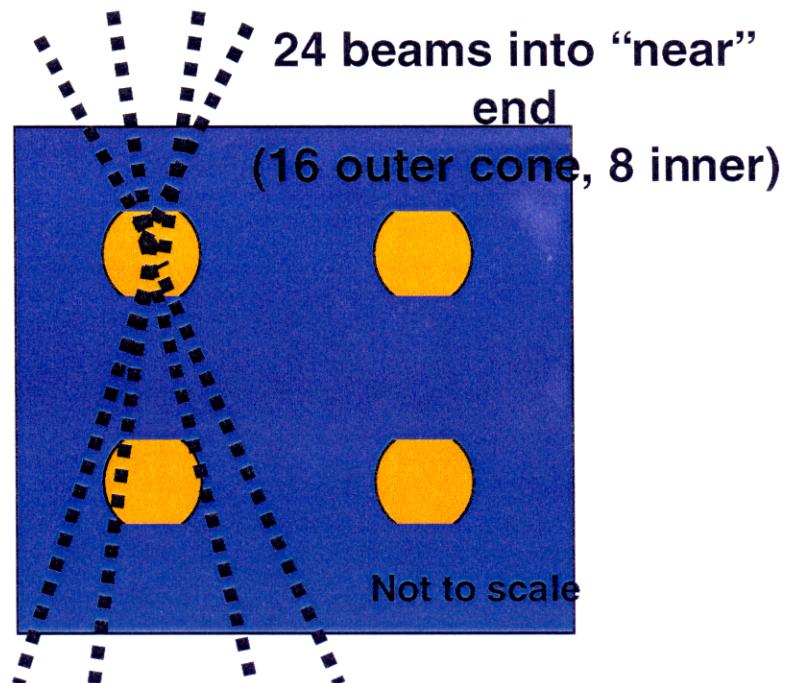
The National Ignition Facility



D leh	D spot max	H spot 50 deg	P per beamlet	I inner	I outer
0.40	0.20	0.13	1.67	5.3E+13	8.3E+13

For distributed sources with beamlets steered to different targets, the single beamlet intensity could be very low

These sources can use 44/48 of NIF



---

**NIF**

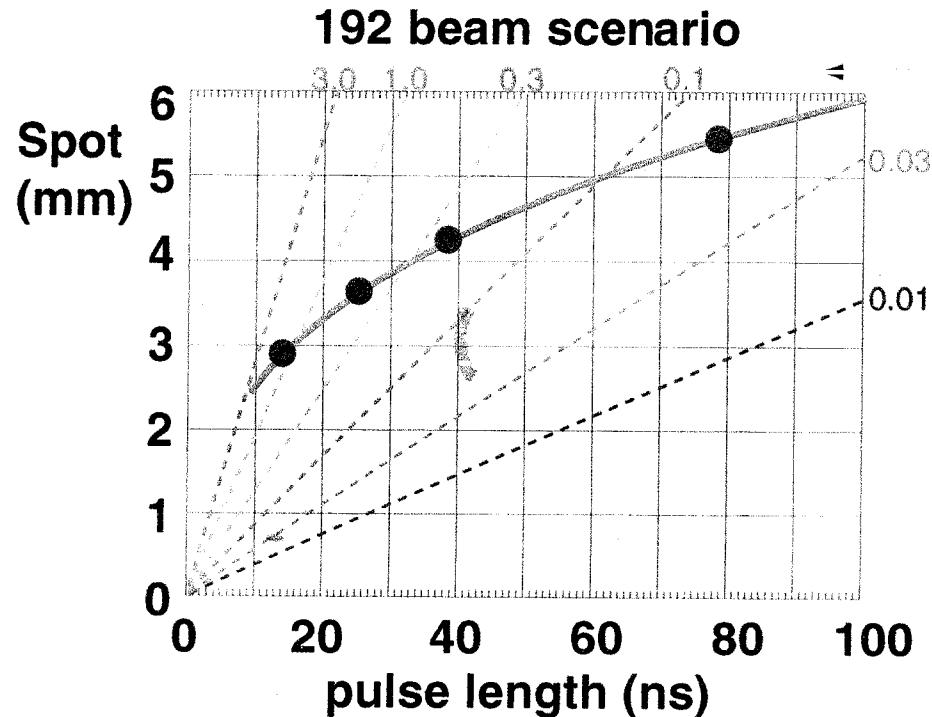
*The National Ignition Facility*

# **Planar hydro experiments**

## **John Edwards**

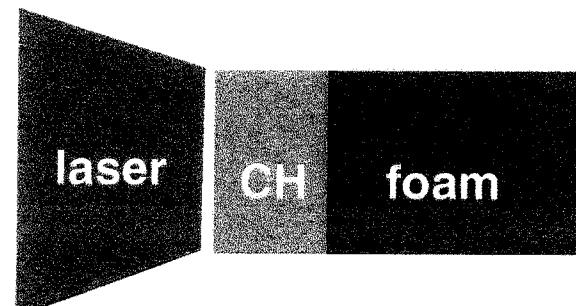
## Planar hydro experiments need the largest spot sizes on NIF

NIF  
The National Ignition Facility



$I (10^{15} \text{ Wcm}^{-2})$

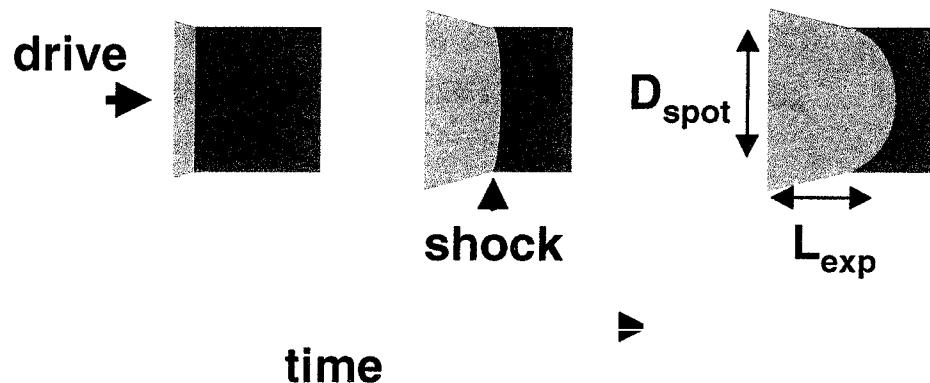
“generic” hydro target



- For a fixed intensity on target spheres need ~ 10% spots relative to planar equivalents
- And symmetry means we can't go to such long pulses for spheres

## We need large spatial scales to make worthwhile experiments

NIF  
The National Ignition Facility



Curvature eventually compromises the data

- To “optimize” designs we make  $L_{\text{exp}} \sim D_{\text{spot}}$
- For each intensity, pulse length combination there is a unique value of  $D_{\text{spot}}$  (depending on target materials)
- This is defining target optimizations for NIF

We often need to stack pulses  
to make large experiments



This is because:

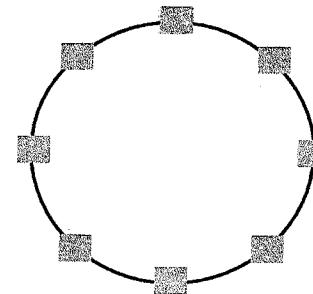
$$L_{\text{exp}} \sim v_{\text{shock}} t \sim I_{\text{las}}^{1/3} t \sim \left( \frac{E}{D^2 t} \right)^{1/3} t$$

But  $L \sim D$  so that

$$L_{\text{exp}} \sim E^{1/5} t^{2/5}$$

But to preserve illumination uniformity  
we require at least 4-fold symmetry

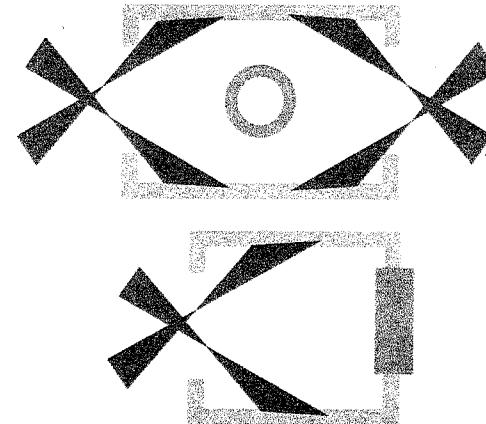
This means we can only get discrete  
pulse lengths (or does it....?)



## Laser spot size is less of an issue for indirect drive

NIF

*The National Ignition Facility*



- The main driver is uniformity/symmetry
- To first order spot size is irrelevant
- The major concerns are:
  - conversion efficiency
  - beam propagation
  - & (of course) LPI

all in a hohlraum constantly filling up with plasma

- Again, hydro experiments need the largest hohlraums up to ~ scale 3 NIF (or more), & longest pulses
- Thus spots could be up to ~ few X ignition spots
- Although optimum spots will be determined thru expt & modeling they should fall within the DD envelope

**We are doing simulations and Omega experiments to help resolve the important issues**



The main question is how long can we go?

**The target design issues are:**

**Direct drive**

- Planarity
- Laser-target coupling vs pulse length & beam angles

**Indirect drive**

- What are limiting factors?
- Drive-target coupling

**This work will help define more precise target designs for NIF**

# **Improvement of the NIF focal spot by diffractive correction**

**NIF**

*The National Ignition Facility*



**Joshua E. Rothenberg**

**WBS-1 Focal Spot Meeting  
February 16, 2000**

# Diffractive Optics can be used to condition the basic NIF focal spot to meet the requirements of the ICF mission



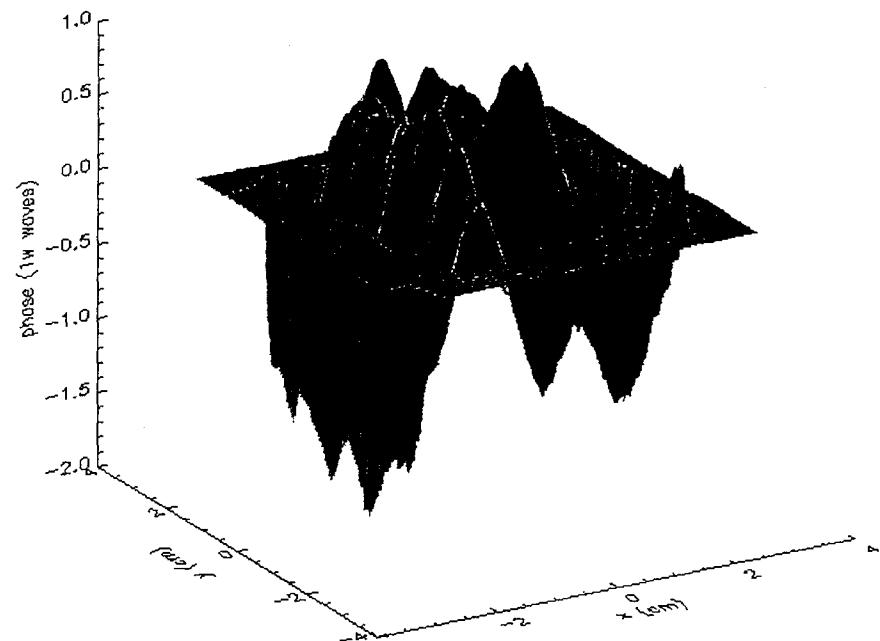
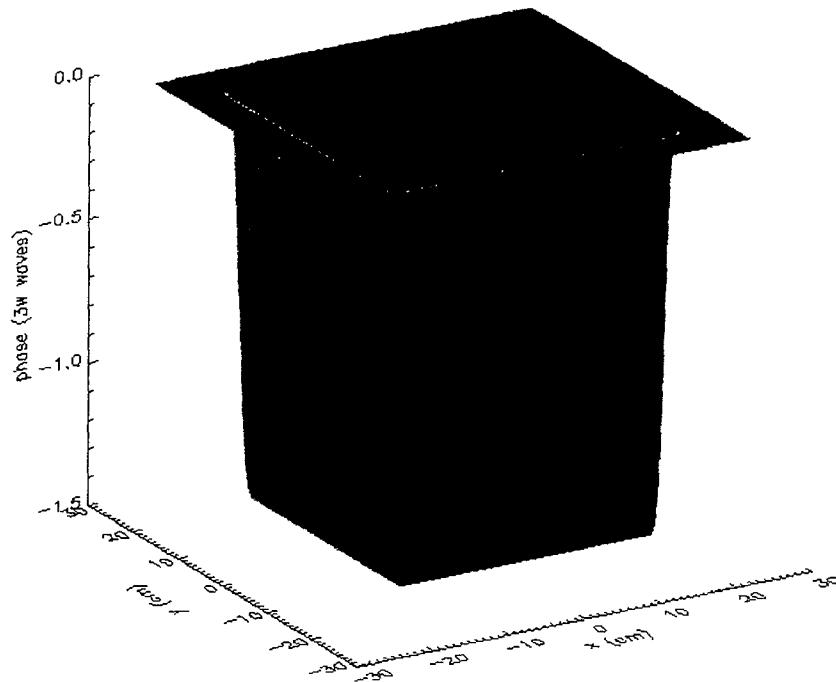
- a KPP can be used to form an elliptical focal spot which optimally fills the LEH such that the peak intensity is reduced to a tolerable level
- a B-integral phase corrector (BIPC) can be used to reduce the focal spot wings (which impinge on the LEH and its associated plasma blow off) originating from whole beam self-focusing. However, the remaining wings may still be too large.
- In conjunction with the BIPC, an aberration corrector in the laser front end can be used to reduce the remaining wings such that the resultant focal spot meets the initial target specifications at the LEH.
- SSD can be used to reduce plasma instabilities resulting from speckle "hot spots" -- at the cost of smearing out the focal spot wings

# We have investigated other phase correction schemes which are not currently part of the baseline laser

The National Ignition Facility



- B-integral corrector plate (part of KPP?)
- passive/pump-induced aberrations corrector plate (in front end?)

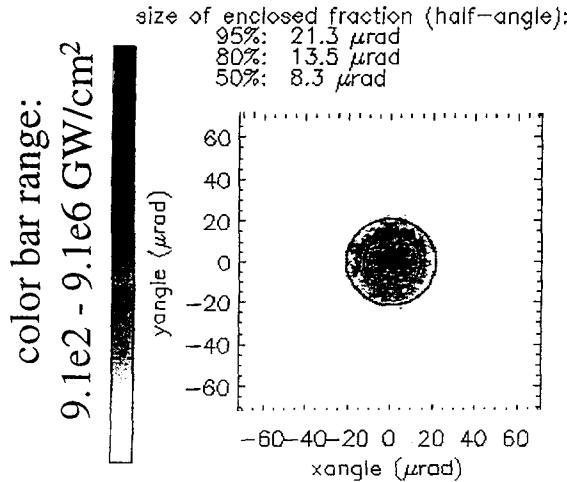


# $3\omega$ spot with various types of correction

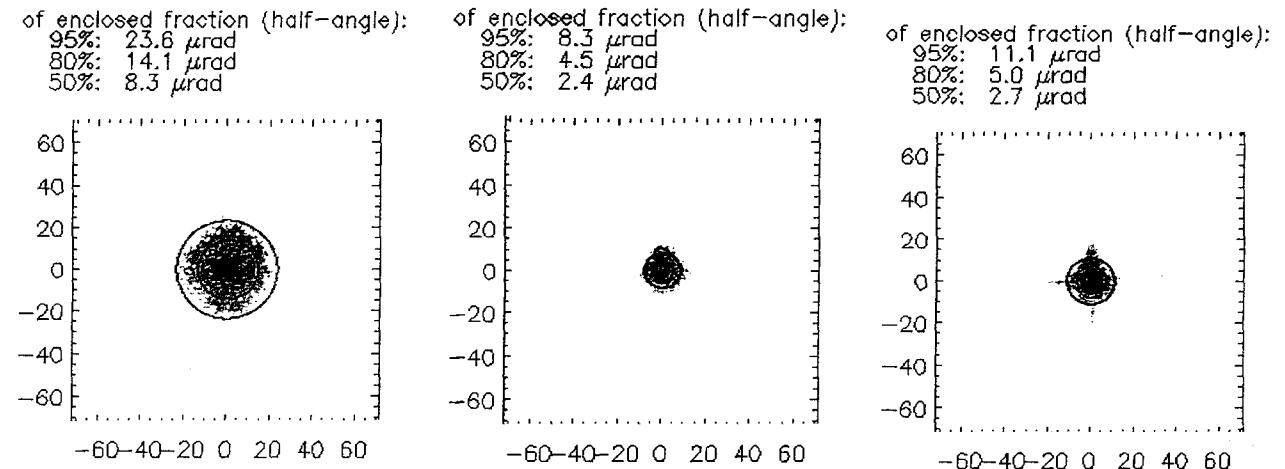
NIF

The National Ignition Facility

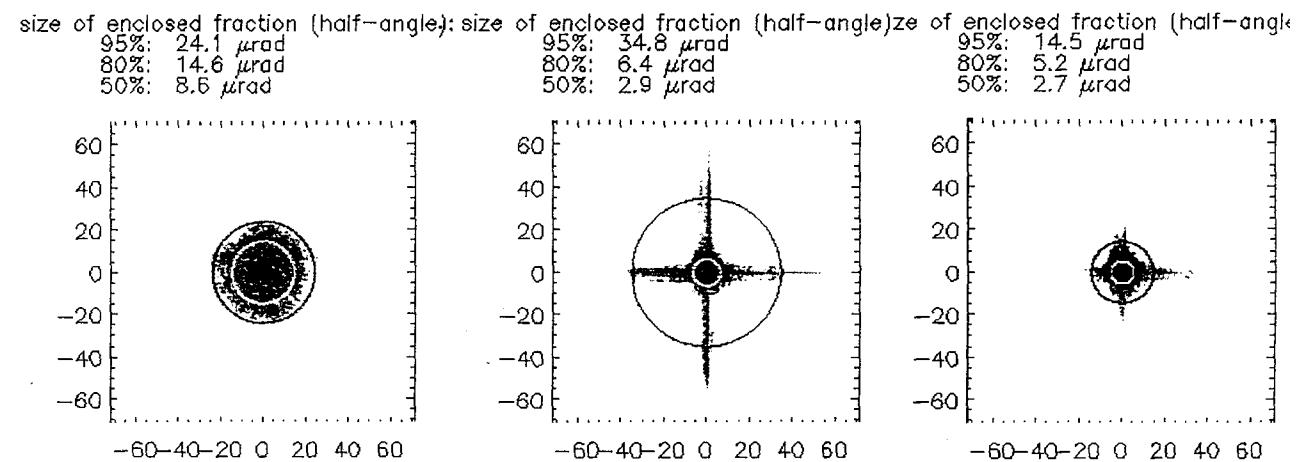
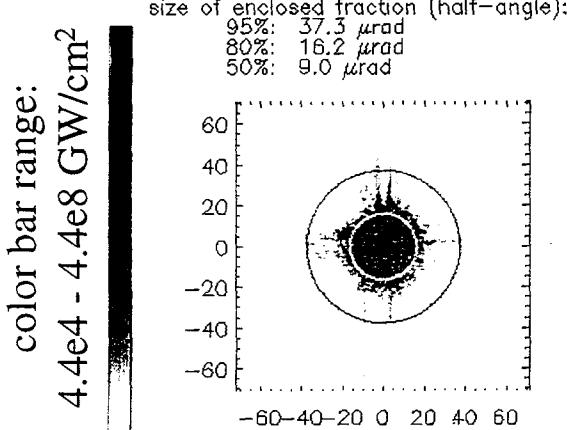
## no correction foot of pulse



## BIPC only ab. corr. only BIPC + ab. corr.



## peak of pulse

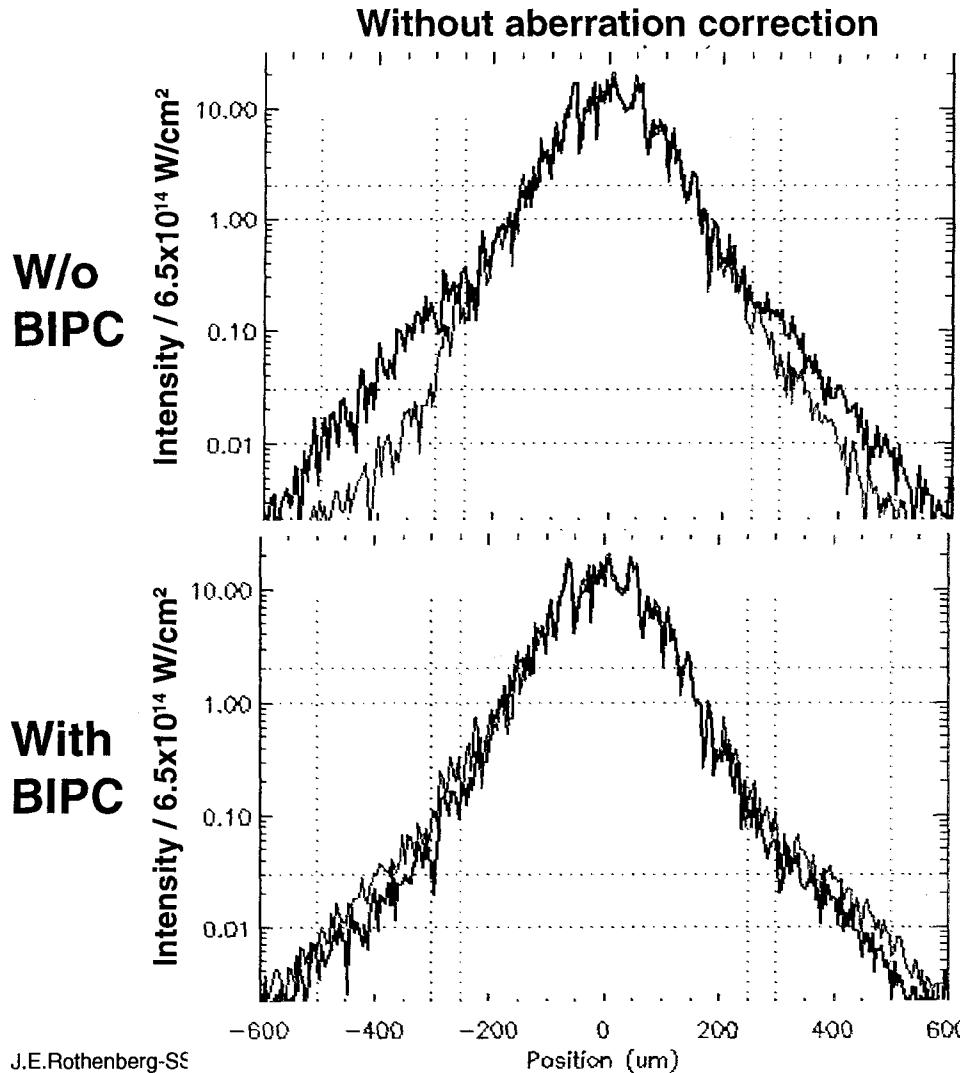


enclosing circles at 80% and 95%

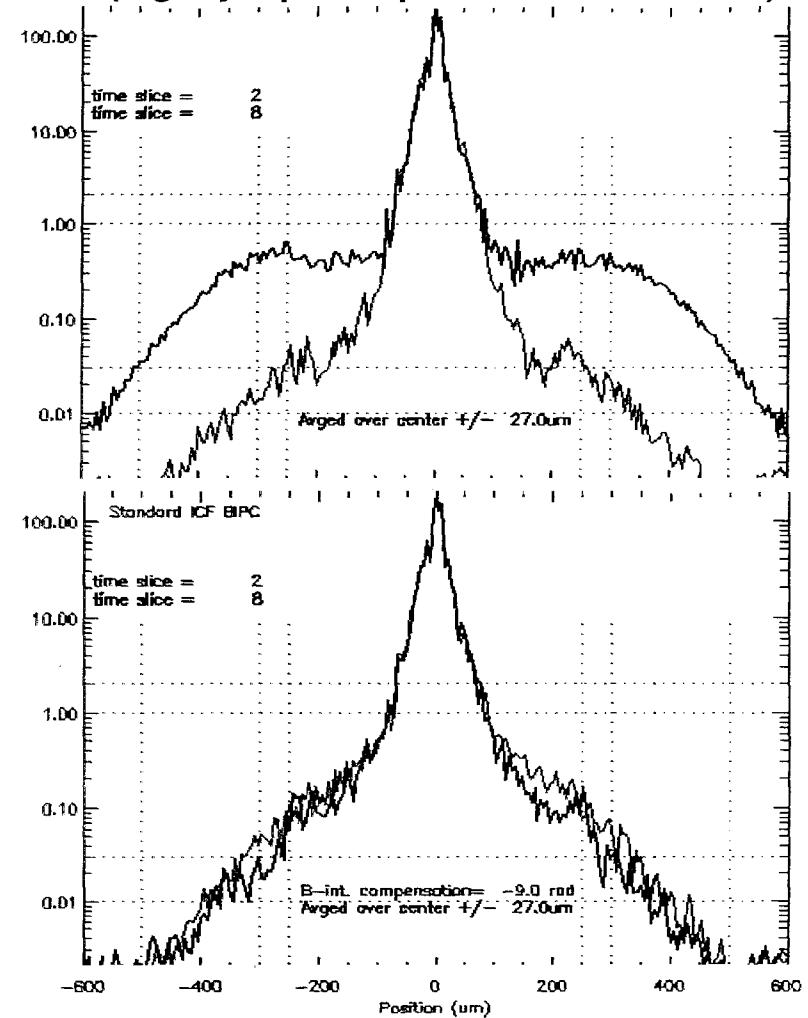
# Phase correction of whole beam self-focusing with the BIPC can reduce the wings, especially when the $1\omega$ optical aberrations at short spatial scale are reduced



Blue curves at peak (2.5 TW) and brown curves in foot (50 GW)



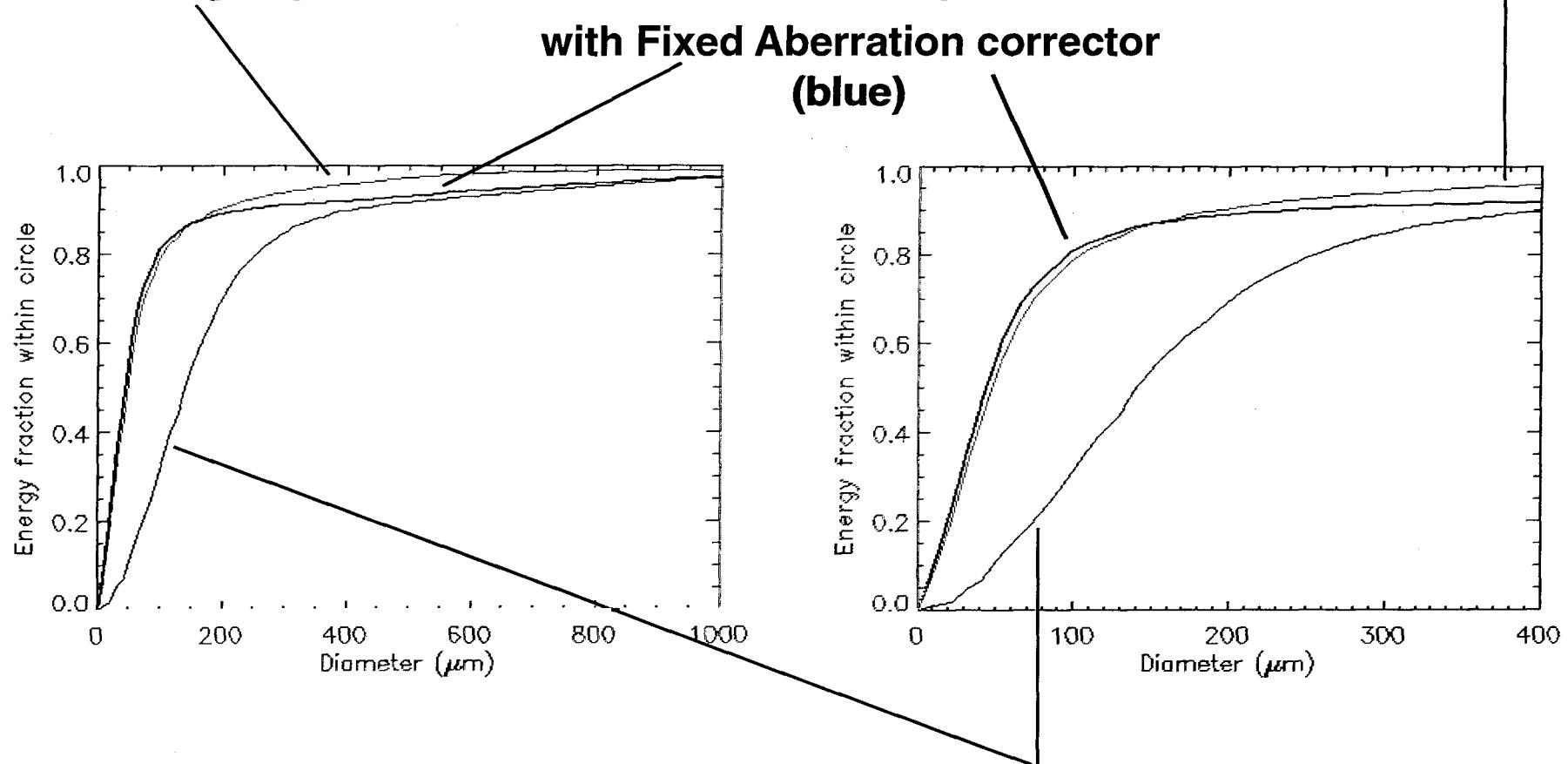
With complete aberration correction  
(e.g. by a phase plate in the front end)



**MUCH better focal spots are possible using a static phase corrector plate (80% energy Diam. 250  $\mu\text{m}$   $\rightarrow$  100  $\mu\text{m}$ )**



with B-integral phase and aberration corrector (green)



**NIF baseline SSMP spot  
(700 TW, 1ns)**

# Calculated energy fractions as a function of diameter for baseline and aberration corrected NIF spots



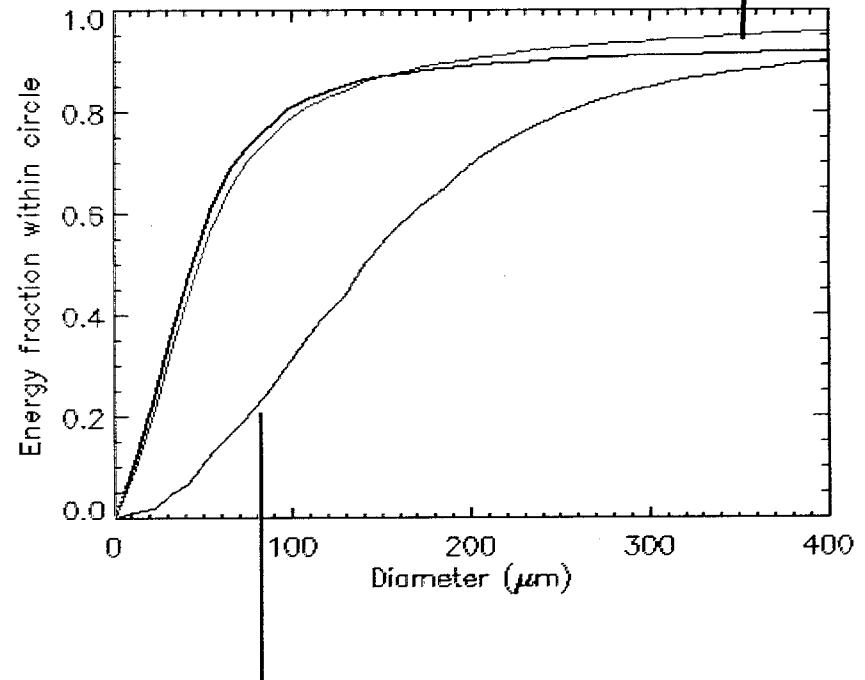
w/correction

Diameter	Energy fraction
0.00000	0.00000
10.8108	0.0987434
21.6216	0.227954
32.4324	0.368667
43.2432	0.491662
54.0540	0.607971
64.8648	0.686555
75.6756	0.735704
86.4864	0.772260
97.2972	0.808491
108.108	0.828530
118.919	0.842351
129.730	0.855544
140.540	0.866747
151.351	0.873223
162.162	0.878551
172.973	0.883215
183.784	0.887425
194.594	0.890572
205.405	0.894175
216.216	0.897073

without correction

Diameter	Energy fraction
0.00000	0.00000
10.8108	0.0117182
21.6216	0.0208129
32.4324	0.0528235
43.2432	0.0727015
54.0540	0.123211
64.8648	0.165715
75.6756	0.202568
86.4864	0.248713
97.2972	0.302193
108.108	0.352430
118.919	0.401881
129.730	0.439810
140.540	0.499434
151.351	0.543560
162.162	0.586622
172.973	0.620531
183.784	0.648846
194.594	0.682651
205.405	0.711537
216.216	0.737749
227.027	0.757952
237.838	0.778337
248.648	0.794796
259.459	0.808221
270.270	0.823035
281.081	0.834496
291.892	0.844571
302.702	0.853051
313.513	0.861217
324.324	0.868287

with aberration corrector (blue)



NIF baseline SSMP spot  
(700 TW, 1ns)